Appendix F

Fire Protection
Significance Determination Process

Intentionally Blank

Appendix F - Table of Contents

Attachments

Tables

Figures

Intentionally Blank

Introduction

The Fire Protection Significance Determination Process (SDP) involves a series of qualitative and quantitative analysis steps for estimating the risk significance of inspection findings related to licensee performance in meeting the objectives of the fire protection defense-in-depth (DID) elements. The fire protection DID elements are:

- Prevention of fires from starting,
- Rapid detection and suppression of fires that occur, and
- Protection of structures, systems, and components (SSCs) important to safety so that a fire that is not promptly extinguished by fire suppression activities will not prevent the safe shutdown (SSD) of the plant.

The Fire Protection SDP is based on simplified methods and approaches of a typical fire PRA. The general philosophy of the Fire Protection SDP is to minimize the potential for false-negative findings, while avoiding undue conservatism. The duration (or exposure time) of the degraded conditions is considered at all stages of the analysis. Compensatory measures (CMs) that might offset (in part or in whole) the observed degradation are considered in Phase 2.

Approach

Phase 1 of the Fire Protection SDP is a preliminary screening check intended for use by the Resident or Regional Office inspector(s) to identify fire protection findings with a very low risk significance. If the screening criteria are met, the finding is assigned a preliminary risk significance ranking of Green and no Phase 2 analysis is required. If the Phase 1 screening criteria are not met, the analysis continues to Phase 2.

Phase 1 involves four analysis steps as illustrated in Figure F.1. The finding is first characterized (Step 1.1) based on the fire protection program element that was found to be degraded. The finding is then assigned a degradation rating (Step 1.2) based on the potential impact the degraded condition might have on the performance of the degraded fire protection program element. An initial qualitative screening check (Step 1.3) is performed based on the answers to two general questions and, if applicable, several additional questions if the finding category is “Fire Confinement.” An initial quantitative screening check (Step 1.4) is performed that considers room fire frequency and the duration factor for the finding.

Phase 2 involves a quantitative assessment of the increase in CDF due to a finding. Phase 2 involves nine analysis steps as illustrated in Figure F.2. Each step represents the introduction of new detail and/or the refinement of previous analysis results.

The Phase 2 analysis includes five distinct screening checks. Each time new or refined analysis results are developed, a screening check is made to determine if a sufficient basis has been developed to justify assignment of a preliminary significance ranking of Green. If at any time the quantitative screening criteria are met, the analysis is considered complete, and subsequent steps need not be performed.

Figure F.1 - Phase 1 Flow Chart

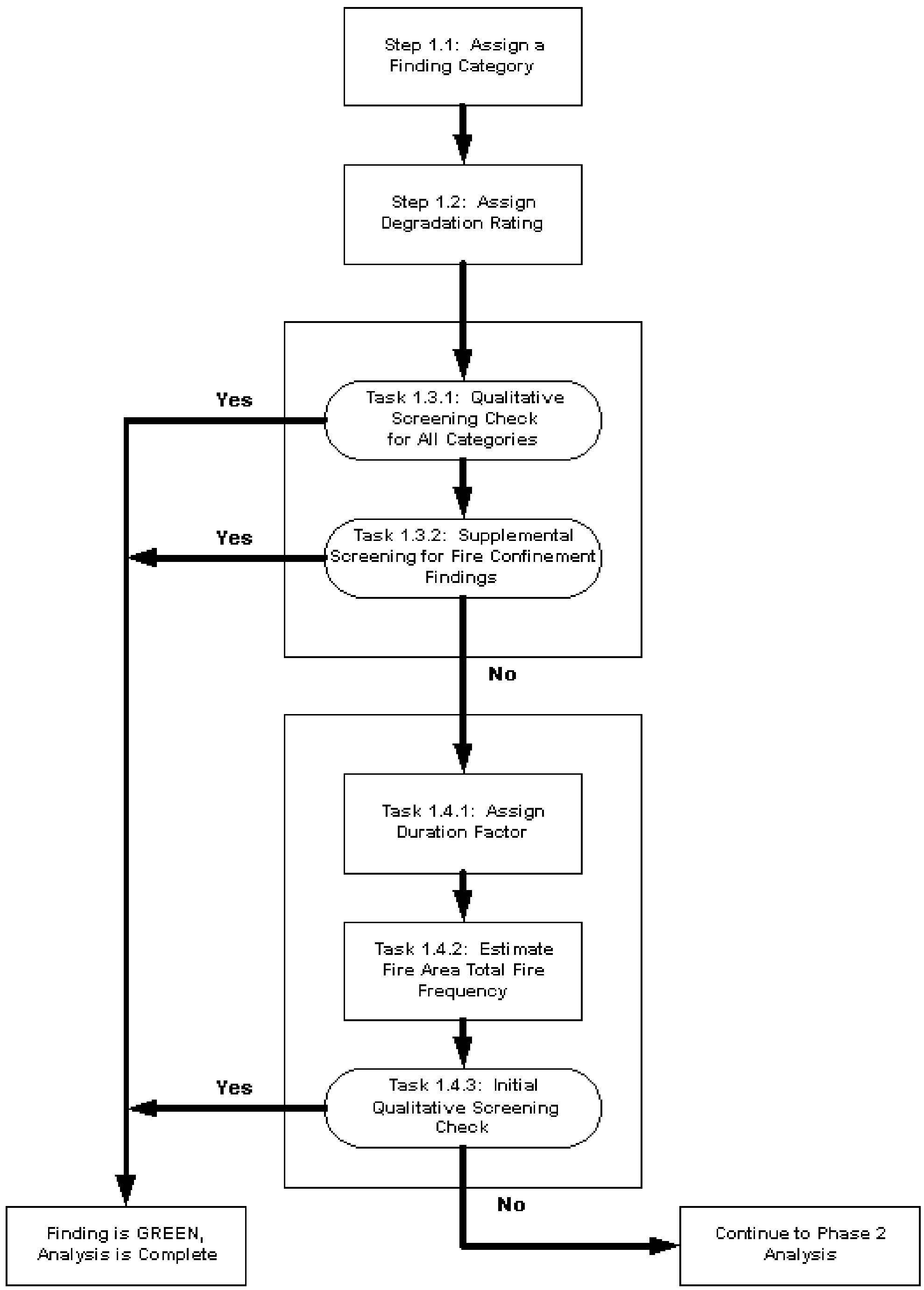
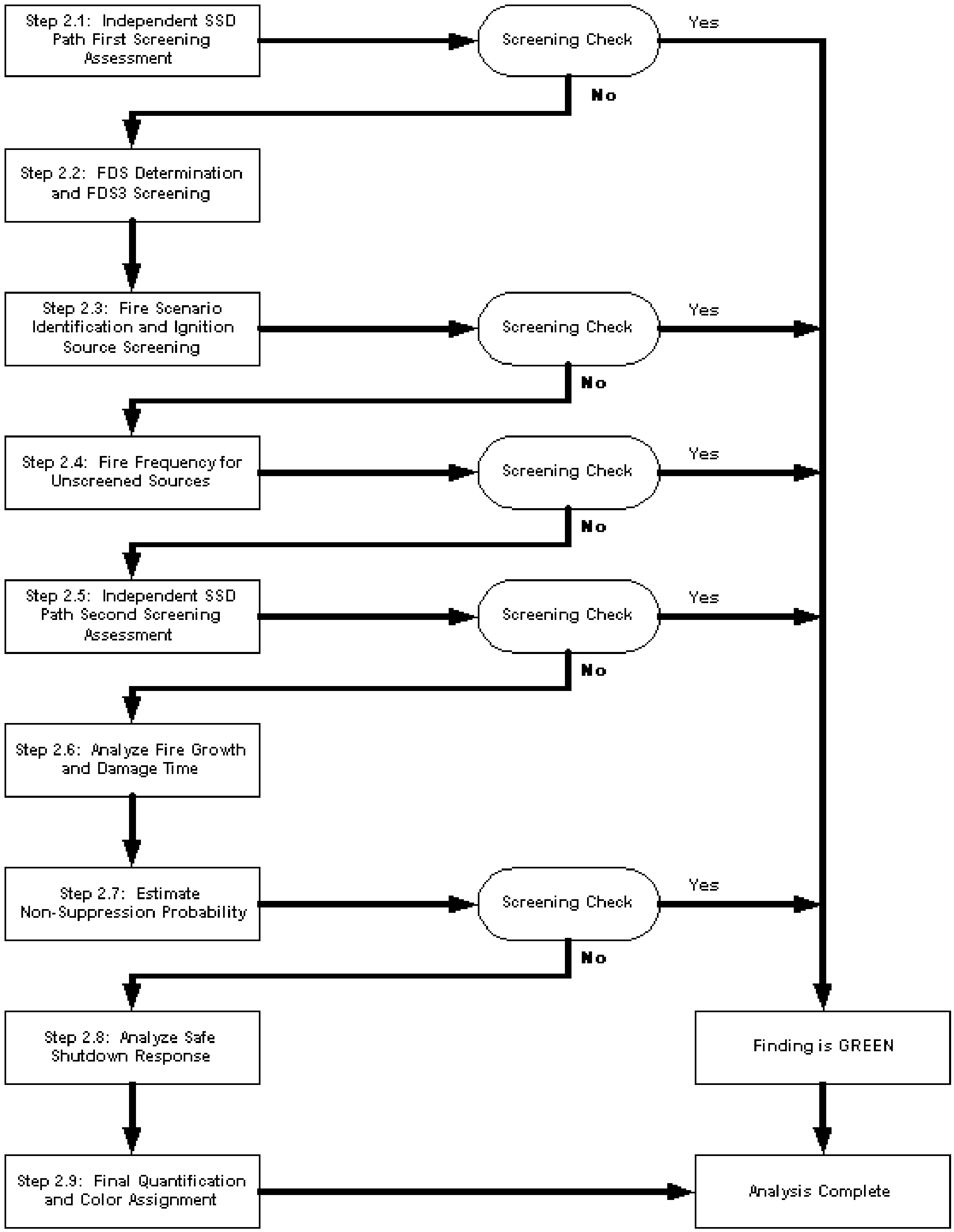


Figure F.2 - Phase 2 Flow Chart



Assumptions and Limitations

This document describes a simplified tool that provides a slightly conservative, nominally order-of-magnitude assessment of the risk significance of inspection findings related to the fire protection program. The Fire Protection SDP is a tool that NRC inspectors can easily use to obtain an assessment of the risk significance of a finding.

The Fire Protection SDP approach has a number of inherent assumptions and limitations. A more detail discussion of these assumptions and limitations is contained in the Supplemental Guidance/Technical Basis for Appendix F (IMC 0308, Att 3, App F).

- The Fire Protection SDP assesses the change in CDF, rather than LERF, as a measure of risk significance.
- The quantification approach and analysis methods used in this Fire Protection SDP are largely based on existing fire PRA analysis methods. As such, the methods are also limited by the current state of the art in fire PRA methodology.
- The Fire Protection SDP focuses on risks due to degraded conditions of the fire protection program during full power operation of a nuclear power plant. This tool does not address the potential risk significance of fire protection inspection findings in the context of other modes of plant operation (i.e., low power or shutdown).
- In the process of simplifying existing fire PRA methods for the purposes of the Phase 2 Fire Protection SDP analysis, compromises in analysis complexity have been made. The process strives to achieve order of magnitude estimates of risk significance. However, it is recognized that fire PRA methods in general retain considerable uncertainty. The Fire Protection SDP strives to minimize the occurrence of false-negative findings.
- The Fire Protection SDP excludes findings associated with the performance of the on-site manual fire brigade or fire department.
- The Fire Protection SDP Phase 2 quantitative screening method includes an approach for incorporating known fire-induced circuit failure modes and effects issues into an SDP analysis. However, the SDP approach is intended to support the assessment of known issues only in the context of an individual fire area. A systematic plant-wide search and assessment effort is beyond the intended scope of the fire protection SDP.
- This document does not currently include explicit treatment of fires in the main control room. The Phase 2 process can be utilized in the treatment main control room fires, but it is recommended that additional guidance be sought in the conduct of such an analysis.
- This document does not currently include explicit treatment of fires leading to main control room abandonment, either due to fire in the main control room or due to fires in other fire areas. The Phase 2 process can address such scenarios, but it is recommended that additional guidance be sought in the conduct of such an analysis.

Fire Protection SDP Phase 1 Qualitative Screening Approach

The Phase 1 qualitative screening approach is entered when the following items are met:

- The inspection finding has a clearly stated licensee performance deficiency.

- The statement of licensee performance deficiency should discuss the noncompliance with any applicable licensing basis requirements. The SDP analysis should not proceed if the condition of the fire protection feature was specifically approved in a Safety Evaluation Report (SER) during the fire protection licensing process.

- The finding is considered “more than minor” based on IMC 0612 criteria.

The worksheet for recording the Fire Protection SDP Phase 1 review is provided in Attachment 1.

Step 1.1 - Assign a Finding Category

Assign a Finding Category based on which element of the plant fire protection program is impacted by the finding. Examples of specific findings applicable to each finding category are illustrated below:

Table 1.1.1 - Examples of Finding Category

Finding Category	Elements of the Fire Protection Program Covered by Each Category
Cold Shutdown	• findings related to the ability to achieve and maintain cold shutdown only
Fire Prevention and Administrative Controls	• the plant combustible material controls program • other administrative controls such as work permit programs • hot work fire watches • roving or periodic fire watches • training programs • compliance documentation
Fixed Fire Protection Systems	• fixed fire detection systems • fixed fire suppression systems (automatic or manual) • fire watches posted as a compensatory measure for a fixed fire protection system outage or degradation
Fire Confinement	• fire barrier elements that separate one fire area from another • penetration seals • water curtains • fire and/or smoke dampers • fire doors
Localized Cable or Component Protection	• passive physical features installed for the thermal/fire protection of cables, cable raceways, or individual components • raceways or component fire barriers (e.g., cable wraps) • radiant heat shields protecting a component or cable • spatial separation (e.g., per App. R Section III.G.2)

Table 1.1.1 - Examples of Finding Category	
Finding Category	**Elements of the Fire Protection Program Covered by Each Category**
Post-fire SSD	• systems or functions identified in the post-fire safe shutdown analysis • systems or functions relied upon for post-fire safe shutdown • post-fire SSD component list (e.g., completeness) • post-fire SSD analysis (e.g., completeness) • post-fire plant response procedures • alternate shutdown (e.g., manual actions) • remote shutdown and control room abandonment • circuit failure modes and effects (e.g., spurious operation issues)

Step 1.2 - Assign a Degradation Rating

Assign a degradation rating reflecting the severity of the observed deficiency. Findings are, in general, rated as reflecting "Low," "Moderate," or "High" degradation of the impacted fire protection program element. Degradation rating guidance that is specific to various fire protection program elements is provided in Attachment 2.

- A **LOW** degradation reflects a fire protection program element whose performance and reliability will be minimally impacted by the inspection finding. That is, the system, feature, or provision impacted by the finding is expected to display nearly the same level of effectiveness and reliability as it would had the degradation not been present.

- A **MODERATE** degradation implies that a fire protection program element displays significant degradation that will impact performance and/or reliability. However, the element impacted by the finding is still expected to provide some substantial DID benefit despite the noted deficiency. (For some DID elements, moderate degradations may be further subdivided, e.g., Moderate A and Moderate B.)

- A **HIGH** degradation implies that the performance or reliability of the fire protection program element is severely degraded such that little or no fire protection benefit is anticipated given the deficiency. High degradation implies that no credit will be given to the degraded fire protection program element in quantification of risk significance.

Step 1.3 - Initial Qualitative Screening

<u>Task 1.3.1: Qualitative Screening for All Finding Categories</u>
For findings in all categories, screen the finding based on the following two questions:

1. Was the finding assigned a LOW degradation rating?
   If Yes - Screen to Green, no further analysis required.
   If No, continue to next question.

2. Does the finding only affect ability to reach and maintain cold shutdown conditions?
   If Yes - Screen to Green, no further analysis required.
   If No, continue to Step 1.4, unless the finding category was "Fire Confinement," in which case, proceed to Task 1.3.2.

Task 1.3.2: Supplemental Screening for Fire Confinement Findings

If the finding category assigned in Step 1.1 is “Fire Confinement” and the degradation rating assigned in Step 1.2 is “Moderate,” perform a supplemental qualitative screening check based on the following questions. Otherwise, proceed to Step 1.4.

The screening criteria are expressed in terms of the fire protection features for the “exposing” and “exposed” fire areas. The “exposing” fire area is the area in which the fire is assumed to start. The “exposed” area is the adjacent space that might be impacted should fire spread from the exposing area, through an inter-area fire barrier, into the exposed area.

1. Will the barrier in its degraded condition provide a 2-hour or greater fire endurance rating?
   If Yes – Screen to Green, no further analysis required
   If No – Continue to next question

2. Is there a non-degraded automatic gaseous room-flooding fire suppression system in the exposing fire area?
   If Yes – Screen to Green, no further analysis required
   If No – Continue to next question

3. Is there a non-degraded or no more than moderately degraded automatic full area water-based fire suppression system in the exposing fire area?
   If Yes – Screen to Green, no further analysis required
   If No – Continue to next question

4. Can it be determined that the exposed fire area contain no potential damage targets that are unique from those in the exposing fire area (damage targets may include post-fire safe shutdown components or other plant components whose loss might lead to a demand for safe shutdown (e.g., a plant trip))?
   If Yes – Screen to Green, no further analysis required
   If No – Continue to next question

5. Are all potential damage targets in the exposed fire area (as described in question 4) provided with passive fire barrier protection with no more than a moderate degradation that will provide a minimum of 20 minutes fire endurance?
   If Yes – Screen to Green, no further analysis required
   If No – Continue to next question

6. Is a non-degraded or no more than moderately degraded partial-coverage automatic water based fire suppression system installed in the exposing fire area and are all the fixed or *in-situ* fire ignition sources included within the zone of coverage for this system?
   If Yes – Screen to Green, no further analysis required
   If No – Continue to next question

7. Does the degraded barrier provide a minimum of 20 minutes fire endurance protection and are the fixed or *in situ* fire ignition sources and combustible or flammable materials positioned such that, even considering fire spread to secondary combustibles, the degraded barrier or barrier element will not be subject to direct flame impingement?
   If Yes – Screen to Green, no further analysis required
   If No – Continue to Step 1.4

Step 1.4 - Initial Quantitative Screening

In Step 1.4, two quantitative factors are considered; namely, total fire frequency for the fire area under analysis, and the finding duration factor. If the product of these two factors is sufficiently small, the finding may be screened to Green without further analysis.

Task 1.4.1: Assign a Duration Factor to the Finding
Assign a duration factor (DF) based on the length of time that the noted performance degradation was, or will be, in existence (i.e., the duration of the degradation). The duration factor is determined from the table below. The duration factor is utilized throughout the balance of both the Phase 1 and Phase 2 analyses.

Table 1.4.1 - Duration Factors

Duration of the Degradation	Duration Factor (DF)
< 3 days	0.01
3 - 30 days	0.1
> 30 days	1.0

Task 1.4.2: Estimate the Fire Frequency for the Fire Area
Estimate the fire frequency for the fire area (or areas) impacted by a deficiency finding using Table 1.4.2 and guidance provided below. For the purposes of the Phase 1 screening, the fire frequency is estimated based on the area-wide fire frequency, rather than based on the fire frequency for any specific fire hazard within the fire area, except as described below. It is intended that the fire frequency assigned in this task conservatively bound all fire hazards in the fire area under analysis.

For certain types of specific findings, the estimate of the fire frequency for the fire ignition sources is limited. These cases are as follows:

- **Findings related to hot work (e.g., a degraded hot work fire watch, or lack of adequate fire prevention/mitigation provisions during hot work)**
  If the finding is against the administrative controls program and is associated with hot work permitting or fire watch elements of the program, then only the potential for hot work fires is considered. No consideration of fires initiated by the fixed or *in situ* fire ignition sources is necessary, because the risk contribution arising from such fires does not change given a finding against the hot work control programs. Note that fires initiated by hot work may well involve the ignition of, or spread to, an *in situ* or transient combustible material (e.g., cables, trash, or stored materials), but the fire ignition source is the hot work activity itself.

- **Violations of the combustible controls program**
  If the finding is against the administrative controls program and is associated with the combustible material control elements of that program, then only fires initiated in or by transient combustible materials need to be considered. Once again, no consideration of fires initiated by the fixed or *in situ* fire ignition sources is necessary, because the risk contribution arising from such fires does not change given a finding against the combustible material control programs. Note that fires initiated in a transient material may well spread to *in situ* combustible materials (e.g., cables or an adjacent electrical panel) but the fire ignition source is the transient combustible material.

Table 1.4.2 - Generic Fire Area Fire Frequencies	
Room Identifier/Limited Specific Findings	**Generic Fire Frequency**
Auxiliary Building (PWR)	4E-2
Battery Room	4E-3
Cable Spreading Room - Cables Only	2E-3
Cable Spreading Room - Cables Plus Other Electrical Equipment	6E-3
Cable Vault or Tunnel Area - Cables Only	2E-3
Cable Vault or Tunnel Area - Cables Plus Other Electrical Equipment	6E-3
Containment - PWR or non-inerted BWR	1E-2
EDG Building	3E-2
Intake Structure	2E-2
Main Control Room	8E-3
Radwaste Area	1E-2
Reactor Building (BWR)	9E-2
Switchgear Room	2E-2
Transformer Yard	2E-2
Turbine Building - Main Deck (per unit)	8E-2
Hot Work Issues Only	2E-3
Combustible Controls Program Issues Only	5E-3

Task 1.4.3: Screening Check

Multiply the fire area fire frequency from Task 1.4.2 by the duration factor from Task 1.4.1 to generate an initial Phase 1 screening change in CDF value ($\Delta CDF_{1.4}$). *Since the probability of non-suppression and CCDP have not been considered yet, they are unwritten, but with an assumed value of 1.0.*

$$\Delta CDF_{1.4} \approx F_{Area} \times DF$$

If the finding impacts multiple fire areas, then the initial Phase 1 screening CDF value is based on the sum of the fire frequency for all impacted fire areas as follows:

$$\Delta CDF_{1.4} \approx (\Sigma F_{Area}) \times DF$$

$\Delta CDF_{1.4}$ is compared to the values in the Table 1.4.3 below. Note that the screening level depends on both the finding category and the assigned degradation rating.

Table 1.4.3 - Phase 1 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	**$\Delta CDF_{1.4}$ Screening Criteria**	
	Moderate Degradation	**High Degradation**
Fire Prevention and Administrative Controls	N/A	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5	
Localized Cable or Component Protection	1E-5	
Post-fire SSD	1E-6	

- If $\Delta CDF_{1.4}$ is lower than the corresponding value in Table 1.4.3, the finding screens to Green and the analysis is complete (no Phase 2 analysis is required).

- If $\Delta CDF_{1.4}$ is greater than or equal to the corresponding value in Table 1.4.3, then the finding does not screen to Green, and the analysis continues to Phase 2.

Fire Protection SDP Phase 2 Quantitative Screening Approach

The worksheet for recording the Fire Protection SDP Phase 2 review is provided in Attachment 1, beginning on page 1-5.

In preparation for the analysis, request and review the following licensee documents:

- The licensee's fire hazards analysis for the fire areas to be evaluated
- The post-fire safe shutdown analysis for the fire areas to be evaluated
- The licensee's lists of required and associated circuits
- Post-fire operating procedures applicable to the fire areas to be assessed
- Documentation for any USNRC approved deviations or exemptions relevant to the fire areas to be assessed.

Step 2.1 - Independent SSD Path First Screening Assessment

Task 2.1.1: Identify the Designated Post-fire SSD Path

Identify the designated post-fire SSD path for the fire area(s) under analysis. All plant fire areas should have such a SSD path identified as a part of the plant's fire protection program. The identified SSD must meet the following criteria in order to be considered at this stage of the Phase 2 analysis:

- The SSD path must be identified as the designated post-fire SSD path in the plant's fire protection program.
- The SSD path must be supported by a documented post-fire SSD analysis consistent with regulatory requirements.
- Use of the SSD path must be documented and included in the plant operating procedures.

Task 2.1.2: Assess the Unavailability Factor for the Identified SSD Path

Assign a SSD unavailability factor to the identified SSD path in its as found condition. The total unavailability factors to be applied in the screening CCDP evaluation are shown in Table 2.1.1.

Certain additional caveats exist for manual actions in the determination of the screening CCDP. These caveats are:

- No credit is given for manual actions impacted by fire effects such as smoke or high temperatures, or by discharge of carbon-dioxide fixed suppression systems.
- Only manual actions which are specifically identified in the respective plant specific procedures can be credited.
- Any credit given for manual actions are compared to the hardware credit with which they are associated and the more conservative value is used.
- If there is any doubt about the feasibility/reliability of executing the manual actions, the SSD unavailability factor is equal to 1.0.

Table 2.1.1 - Total Unavailability Values for SSD Path Based Screening CCDP	
Type of Remaining Mitigation Capability	**Screening Unavailability Factor**
1 Automatic Steam-Driven (ASD) Train: A collection of associated equipment that includes a single turbine-driven component to provide 100% of a specified safety function. The probability of such a train being unavailable due to failure, test, or maintenance is assumed to be approximately 0.1 when credited as "Remaining Mitigation Capability."	0.1
1 Train: A collection of associated equipment (e.g., pumps, valves, breakers, etc.) that together can provide 100% of a specified safety function. The probability of this equipment being unavailable due to failure, test, or maintenance is approximately 1E-2 when credited as "Remaining Mitigation Capability."	0.01
Operator Action Credit:: Major actions performed by operators during accident scenarios (e.g., primary heat removal using bleed and feed, etc.). These actions are credited using three categories of human error probabilities (HEPs). These categories are Operator Action = 1.0 which represents no credit given, Operator Action = 0.1 which represents a failure probability between 5E-2 and 0.5, Operator Action = 0.01 which represents a failure probability between 5E-3 and 5E-2. Credit is based upon the following criteria being satisfied: (1) sufficient time is available; (2) environmental conditions allow access, where needed; (3) procedures describing the appropriate operator actions exist; (4) training is conducted on the existing procedures under similar conditions; and (5) any equipment needed to perform these actions is available and ready for use.	1.0, 0.1 or 0.01

Task 2.1.3: Assess Independence of the Identified SSD Path

Crediting of any SSD path prior to the development of specific fire damage scenarios requires that a high level of independence be verified. Once the designated post-fire SSD path has been identified, verify the following characteristics of this SSD path:

- The licensee has identified and analyzed the SSD SSCs required to support successful operation of the SSD path.
- The licensee has identified and analyzed SSCs that may cause mal-operation of the SSD path (e.g., the required and associated circuits).
- The licensee has evaluated any manual actions required to support successful operation of the SSD path and has determined that the actions are feasible.
- All manual actions take place outside the fire area under analysis.
- The licensee has conducted an acceptable circuit analysis.
- Any known unresolved circuit analysis issues that could adversely impact the functionality of the designated SSD path are identified.
- No known circuit analysis issues (e.g., a known spurious operation issue) for exposed cables should hold the potential to compromise functionality of the identified SSD path.
    - Cables within the fire area under analysis are not considered exposed if they are protected by a non-degraded raceway fire barrier with a minimum 3-hour fire endurance rating.

   - Cables within the fire area under analysis <u>are not</u> considered exposed <u>if</u> they are protected by a raceway fire barrier with a minimum one-hour fire endurance rating, the area is provided with automatic detection and suppression capability, and none of these elements is found to be degraded.
   - Cables in an adjoining fire area <u>are not</u> considered exposed <u>if</u> the fire barrier separating adjoining fire area from the fire area under analysis is not degraded.
   - If the finding category assigned in Step 1.1 was "Fire Confinement," cables located in the adjacent fire area are considered exposed <u>unless</u> they are protected by a non-degraded localized fire barrier with a minimum 1-hour fire endurance rating.
- The licensee's compliance strategy for the separation of redundant safe shutdown circuits (i.e., in the context of Appendix R Section III.G.2) are identified. If the finding category assigned in Step 1.1 is "Fire Confinement," any required or associated circuit components or cables that are located in the adjacent fire area(s) separated by the degraded fire barrier element are identified. Also, any supplemental fire protection (i.e., beyond separation by the degraded barrier element) provided for any such cable or components are identified.
- A second aspect of the independence check depends on the nature of the fire protection that has been provided for the designated SSD path (i.e., in the context of 10CFR50 Appendix R Section III.G.2). Table 2.1.2 provides a matrix of independence criteria for the major options under III.G.2.

Table 2.1.2 - SSD Path Independence Check Criteria

Section III.G.2 compliance strategy for SSD path	**Step 2.1 SSD path independence criteria (all criteria for a given strategy must be met)**
Physical separation into a separate fire area	• The fire area boundary separating the SSD path is not impacted by the finding under analysis.
Separation by a 3-hour rated localized fire barrier (e.g., a raceway barrier)	• The fire barrier qualification rating is not in question, and • The fire barrier protecting the redundant train is not impacted by the finding.
Separation by a 1-hour rated localized fire barrier (e.g., a raceway barrier) plus automatic fire detection and suppression coverage for the fire area	• The fire barrier qualification rating is not in question, • The fire barrier protecting the redundant train is not impacted by the finding, • The fire detection system is not impacted by the finding, and • The fire suppression system is not impacted by the finding.
Spatial separation or other means of protection (e.g., exemptions, deviations, reliance on remote shutdown)	• SSD Path will <u>not be credited</u> pending further refinement of the SDP fire scenarios

If the designated post-fire SSD path meets the established physical independence criteria, its unavailability is credited for all fire scenarios: $CCDP_{2.1.3} = CCDP_{2.1.2}$ = (SSD Unavailability Factor). If any of the independence criteria are not met, the SSD path is not credited (i.e., $CCDP_{2.1.3} = 1.0$).

NOTE: Steps 2.5-2.7 include the possibility of crediting the identified SSD path in the context of specific fire scenarios and specific Fire Damage States (FDSs). Hence, the unavailability estimates for the identified SSD path should not be discarded, even if they will not be applied at this stage of the analysis. Rather, the results should be retained for potential use in these later steps.

Task 2.1.4: Screening Check

If the identified SSD path was assigned an unavailability factor of 1.0 from either $CCDP_{2.1.2}$ or $CCDP_{2.1.3}$, proceed to step 2.2. Task 2.1.4 will provide no added screening benefit over Step 1.4. Otherwise, multiply the duration factor (from Task 1.4.1) by the sum of the fire area fire frequencies (from Task 1.4.2) and by the SSD Unavailability Factor ($CCDP_{2.1.2}$) to generate the Phase 2 Screening, Step 1 change in CDF value ($\Delta CDF_{2.1}$):

$$\Delta CDF_{2.1} \approx DF \times (\Sigma F_{Area}) \times CCDP_{2.1.2}$$

$\Delta CDF_{2.1}$ is compared to the values in Table 2.1.3 or A1.2. The screening level depends on both the finding category and the assigned degradation rating.

Table 2.1.3 - Phase 2 Screening Step 1 Quantitative Screening Criteria

Assigned Finding Category (from Step 1.1):	**$\Delta CDF_{2.1}$ screening value**	
	Moderate Degradation	**High Degradation**
Fire Prevention and Administrative Controls	N/A	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5	
Localized Cable or Component Protection	1E-5	
Post-fire SSD	1E-6	

- If $\Delta CDF_{2.1}$ is lower than the corresponding value in Table 2.1.3, the finding screens to Green and the analysis is complete.
- If $\Delta CDF_{2.1}$ is greater than or equal to the corresponding value in Table 2.1.3, then the finding does not screen to Green, and the analysis continues to Step 2.2.

Step 2.2 - Fire Damage State Determination

Based on the finding category assigned in Step 1.1, analyze to determination which Fire Damage State (FDS) scenarios apply.

The FDS is a discrete stage of fire growth and damage postulated in the development of Fire Protection SDP fire scenarios. Four fire damage states are defined as follows:

> *FDS0:* Only the fire ignition source and initiating fuels are damaged by the fire. FDS0 is not analyzed in the FP SDP as a risk contributor.
> *FDS1*: Fire damage occurs to unprotected components or cables located near the fire ignition source.
> *FDS2*: Widespread fire damage occurs to unprotected components or cables within the fire area of fire origin, to components or cables protected by a degraded local fire barrier system (e.g., a degraded cable tray fire barrier wrap), or to components or cables protected by a non-degraded one-hour fire barrier.
> *FDS3*: Fire damage extends to a fire area adjacent to the fire area of fire origin, in general, due to postulated fire spread through a degraded inter-area fire barrier element (e.g., wall, ceiling, floor, damper, door, penetration seal, etc.).

Task 2.2.1 - Initial FDS Assignment
Using the FDS/Finding Category Matrix in Table 2.2.1 below, identify the FDSs that need to be retained given the finding category assigned in Step 1.1.

Table 2.2.1 - FDS/Finding Category Matrix

Finding Type or Category:	**FDS1**	**FDS2**	**FDS3**
Fire Prevention and Administrative Controls	Retain	Retain	Retain
Fixed Fire Protection Systems	Retain	Retain	Retain
Fire Confinement	N/A	N/A	Retain
Localized Cable or Component Protection Given a High degradation Given a Moderate degradation	 Retain(1) N/A	 Retain Retain	 Retain Retain
Post-fire SSD	Retain	Retain	Retain

Note 1: For a highly degraded local barrier, the protected components/cables are treated as fully exposed and may be assumed damaged in FDS1 scenarios, depending on their proximity to the fire ignition source.

Task 2.2.2: Screening Assessment for FDS3 Scenarios
If the finding category assigned Step 1.1 is “Fire Confinement,” retain the FDS3 scenarios and continue the analysis with Step 2.3. For all other finding categories, conduct a screening check for the FDS3 scenarios based on the following questions. If the FDS3 scenarios “screen out,” the subsequent analysis task for that finding need not consider any FDS3 fire scenarios.

The screening criteria are expressed in terms of the fire protection features for the “exposing” and “exposed” fire areas. The “exposing” fire area is the area in which the fire is assumed to start. The “exposed” area is the adjacent space that might be impacted should fire spread from the exposing area, through an inter-area fire barrier, into the exposed area.

1. Does the fire barrier separating the exposed and the exposing fire areas have a non-degraded 2-hour or greater fire endurance rating?
   If Yes – FDS3 scenarios screen out, continue to Step 2.3.
   If No – continue to next question.

2. Is there a non-degraded automatic gaseous room-flooding fire suppression system <u>either</u> in the exposed <u>or</u> in the exposing fire area?
   If Yes – FDS3 scenarios screen out, continue to Step 2.3.
   If No – continue to next question.

3. Is there a non-degraded <u>or</u> no more than moderately degraded automatic full area water-based fire suppression system <u>either</u> in the exposed <u>or</u> in the exposing fire area?
   If Yes – FDS3 scenarios screen out, continue to Step 2.3.
   If No – continue to next question.

4. Can it be determined that the exposed fire area contain no potential damage targets that are unique from those in the exposing fire area (damage targets may include post-fire safe shutdown components or other plant components whose loss might lead to a demand for safe shutdown (e.g., a plant trip))?
   If Yes – FDS3 scenarios screen out, continue to Step 2.3.
   If No – continue to next question.

5. If the exposed fire area <u>does</u> contain post-fire safe shutdown components <u>or</u> components whose fire-induced failure might lead to a demand for safe shutdown, are all such components located at least 20 feet from the intervening fire barrier, and/or provided with passive fire protection with a minimum one-hour fire endurance rating?
   If Yes – FDS3 scenarios screen out, continue to Step 2.3.
   If No – continue to next question.

6. Is a partial-coverage automatic water based fire suppression system installed in the exposing fire area <u>and</u> are all the fixed or *in-situ* fire ignition sources included within the zone of coverage for this system?
   If Yes – FDS3 scenarios screen out, continue to Step 2.3.
   If No – continue to next question.

7. Does the fire barrier provide a minimum of 20 minutes fire endurance protection <u>and</u> are the fixed or *in situ* fire ignition sources and combustible or flammable materials in the exposing fire area positioned such that, even considering fire spread to secondary combustibles, the barrier will not be subject to direct flame impingement?
   If Yes – FDS3 scenarios screen out, continue to Step 2.3.
   If No – retain the FDS3 scenarios and continue the analysis with Step 2.3.

Step 2.3 - Fire Scenario Identification and Ignition Source Screening

In this step, a screening analysis is performed to eliminate (screen out) fire ignition sources that cannot cause fire to spread to secondary combustibles and cannot cause damage to one or more components/cables in the fire area. Fire ignition sources that are screened out are not analyzed further and are excluded from the refined fire area fire frequency. For unscreened fire ignition sources, specific fire growth and damage scenarios (ignition source and damage target set combinations) are identified corresponding to each applicable FDS. Specific guidance for identifying fire growth and damage scenarios is provided in Attachment 3.

<u>Task 2.3.1: Identify and Count Fire Ignition Sources</u>
Identify fire ignition sources for the fire scenarios within the fire area(s) being evaluated. Fire ignition sources are binned by type or general classifications that are pre-defined in Attachment 1, Table A1.3. All fire ignition sources are assigned to one, and only one, of the identified fire ignition source type bins. Each fire ignition source bin has a corresponding fire scenario characterization bin or bins as identified in Attachment 4, Table A4.1. Cataloging of the fire ignition sources includes a count of the number of fire ignition sources of each type present.

If a finding is related to the degradation of specific portions of a water-based fire suppression system, it may be appropriate to limit the fire ignition source search to those sources whose coverage is impacted by the specific degradation.

One fire ignition source scenario that is applicable to all areas of the plant is transient fuel fires (e.g., trash, refuse, temporary storage materials, etc.).

> *NOTE: In the specific case of findings categorized as “Fire Confinement” in Step 1.1, the fire ignition sources located on BOTH sides of the degraded fire barrier must identified and counted. That is, the scope of Task 2.3.1 and subsequent steps expands to encompass two or more fire areas; and in particular, those fire areas that are separated by the degraded fire barrier element(s).*

For most fire ignition sources, the fire frequency is provided on a per component basis. However, for non-qualified cables, transients, and hot work a likelihood rating assignment as low, medium, or high is required. The guidance for assigning these ratings is provided in Attachment 4.

- Non-qualified Cables
  Cables can be found practically at every part of a nuclear power plant and are the primary focus of a fire risk analysis. For the purposes of fire frequency calculation, each area is ranked according to the quantity of non-qualified cables located in the area.

- Transients
  The assignment of a relative transient fire likelihood rating focuses on the following factors:
    - Extent of general plant personnel traffic passing through an area
    - Normal occupancy during at-power operations
    - The frequency of maintenance activities undertaken in the area
    - Storage practices for transient materials
    - Restrictions imposed by administrative controls

- Hot Work
  The same likelihood rating assigned to the fire area for transient fires is also used as the initial hot work fire likelihood rating. However, plant specific conditions may be considered if such information is readily available, and an alternate hot work likelihood rating may assigned as appropriate.

No other specific cases of a similar nature have been identified. However, should a fire protection program degradation finding be encounter that is very specific to fires involving one or more specific fire ignition sources, then the SDP Phase 2 analysis should be focused on only those specific sources. It is recommended that additional guidance and support in making such a decision should be sought in such cases. Careful and complete documentation of the decision will also be required.

Counting notes and guidelines are provided for each fire ignition source bin. (See Attachment 4 for counting guidance and for information on other aspects of fire ignition source treatment.)

<u>Task 2.3.2: Characterize Fire Ignition Sources</u>
For each unique fire ignition source identified in Task 2.3.1, fire intensity levels, fire severity characteristics and a nominal location are assigned. Fire ignition sources are classified into general types - 'simple' and 'non-simple.'

- Simple fire ignition sources are assigned fire intensity characteristics on a generic basis using predefined guidance (see Table 2.3.1). Most fixed fire ignition sources are of the simple type. To address the uncertainty in fire source severity, each fire ignition source is associated with two heat release rate (HRR) values:
  - The lower HRR value reflects the anticipated or expected fire severity (50th percentile fire), and will be associated with 90% of fires (a fire severity factor of 0.9).
  - The higher HRR value reflects a high confidence limit fire severity (95^{th} percentile fire) and will be associated with 10% of fires (a fire severity factor of 0.1).

- Non-simple fire ignition sources are either unique or require the application of case-specific information. These 'Non-Simple' Fire Ignition Sources include the following:
  - Self-ignited cable fires,
  - Energetic arcing electrical faults leading to fire,
  - Transient fuel fires when the nominal as-found conditions exceed the nominal fire intensity values,
  - Hot work fires,
  - Liquid fuel spill fires including fires in the main turbine generator set, and
  - Hydrogen fires.

  Guidance for treating non-simple fire ignition sources is provided in Attachment 5.

Table 2.3.1 - Mapping of General Fire Scenario Characterization Type Bins to Fire Intensity Characteristics						
Fire Size Bins	**Generic Fire Type Bins with Simple Predefined Fire Characteristics**					
	Small Electrical Fire	**Large Electrical Fire**	**Indoor Oil-Filled Transformers**	**Very Large Fire Sources**	**Engines and Heaters**	**Solid and Transient Combustibles**
70 kW	50th Percentile Fire				50th Percentile Fire	50th Percentile Fire
200 kW	95th Percentile Fire	50th Percentile Fire			95th Percentile Fire	95th Percentile Fire
650 kW		95th Percentile Fire	50th Percentile Fire	50th Percentile Fire		
2 MW			95th Percentile Fire			
10 MW				95th Percentile Fire		

A nominal location, or locations, is also assigned to each unique fire ignition source:

- For most stand-alone fire ignition sources, the location assigned is obvious and corresponds to the location of the individual ignition source.
- For certain types of fire ignition sources, individual fire ignition sources of the same type may be grouped for the purposes of analysis. One location is assigned to represent the group. Grouping of fire ignition sources is most commonly applied in the analysis of electrical panel fires. (See Section 5.2.3.2 of the IMC 0308, Att3, App F for further details.)
- For certain fire ignition sources, multiple locations may apply. This applies to non-fixed sources such as transient fuel fires, hot work fires, oil spill fires, and self-ignited cable fires.

Task 2.3.3: Identify Nearest and Most Vulnerable Ignition or Damage Targets
For each unique fire ignition source scenario, identify the ignition and/or damage targets that will be:

- Secondary combustible materials directly above the fire ignition source that might be ignited by the flame zone and/or plume,
- Secondary combustible materials within a direct line of sight of the fire ignition source that might be ignited by direct radiant heating,
- Thermal damage targets (components or cables) directly above the fire ignition source that might be damaged by the flame zone or plume effects,

- Thermal damage targets (components or cables) within a direct line of sight of the fire ignition source that may be damaged direct radiant heating, and
- The most fragile thermal damage target in the general fire area (for hot gas layer exposures considerations).

Record each ignition and/or damage target and its distance from the appropriate fire ignition source on the Attachment 1 Worksheet, Table A1.4.

The ignition and/or damage of any one target by any means of fire exposure is sufficient to prevent screening of a fire ignition source. Therefore, all potential targets or exposure modes need not be exhaustively explored once an ignited or damaged target and exposure mode are identified.

Additional guidance for the identification of targets and their ignition and damage criteria is provided in Attachment 6.

<u>Task 2.3.4: Fire Ignition Source Screening</u>
Assess the fire spread/damage potential of each fire ignition source using the zone of influence charts (plume and radiant effects) and a correlation for hot gas layer temperature prediction.

Fire ignition sources will be screened out if they meet the following criteria:

1. The fire ignition source cannot cause ignition of secondary combustible fuels, **and**
2. The fire ignition source cannot cause damage consistent with any of the fire damage state scenarios of interest.

If a fire ignition source does not screen out for either of its fire intensity conditions, then both the higher and lower intensity characteristics are retained for consideration in subsequent analysis steps.

In some cases, the fire ignition source may screen out at the lower intensity fire characteristics, but will not screen out at the higher intensity fire characteristics. In this case, the fire ignition source <u>is</u> retained, but <u>only</u> at the higher fire intensity.

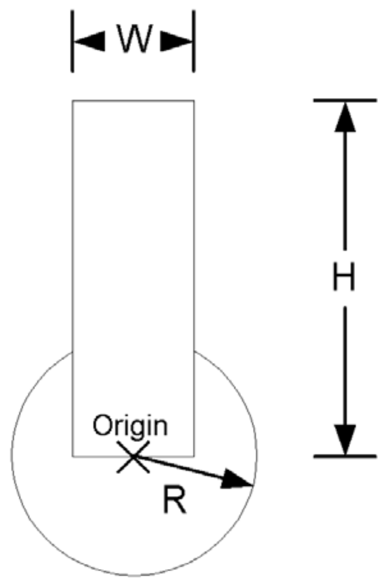
The screening analysis may eliminate potential fire source locations rather than elimination of the fire source in its entirety. For example, transient fuel fires will likely be retained only in specific locations, such as, directly below or adjacent to an ignition or damage target. Screen out transient fires if there are no locations where a fire might cause spread/damage. If at least one location is identified where the transients can cause spread/damage, retain the transient fire scenario.

Similarly, it may be possible to eliminate some electrical panels as non-threatening while others may be retained for further analysis based on their proximity to secondary combustibles and/or damage targets. In this situation, recount the number of electrical panels based on a count of the retained panels.

<u>Zone of Influence Chart</u>
The zone of influence chart is based on consideration of the fire plume and radiant heating effects. The fire plume is represented by a cylinder that extends above the fire source. The diameter of the cylinder (W) is based on the diameter of the fire ignition source itself. The

height of the cylinder is calculated based on the ignition temperature threshold for targets located above the fire source.

The tables that follow (Tables 2.3.2 thru 2.3.4) provide pre-solved thermoplastic cable and thermoset cable critical distances for plume heights (H) and radial distances (R) for each of five discrete fire intensity levels that correspond to the simple fire ignition source types. If the distance from the fire source to the cables is greater than the distance value in the table, the cables are outside the zone of influence for that fire source. The pre-solved values are based on a point source, but the critical distance for plume height (H) should be applied at the diameter boundary (W) of the fire ignition source itself.



The origin is placed at the assigned fire location. Generally this is the top of the fire ignition source itself (i.e., top of the fuel package). Exceptions are as follows:

- For electrical cabinets, the origin is 1 foot below the top of the cabinet.
- For oil or liquid fuel spill fires, the origin is on the floor at the center of the spill.
- For transient fires, the origin is placed 2 feet above the floor at the center of the postulated location.
- For a hydrogen or other gas fire, the origin is at the point of release.

For fires in an open area away from walls or corners:

Table 2.3.2 - Calculated Values (in feet) for Use in the Ball and Column Zone of Influence Chart for Fires in an Open Location Away from Walls				
Fire HRR	**Thermoplastic Cables**		**Thermoset Cables**	
	H	**R**	**H**	**R**
70 kW	4.8	1.8	3.5	1.3
200 kW	7.3	3.0	5.3	2.1
650 kW	11.6	5.4	8.5	3.8
2 MW	18.2	9.5	13.3	6.7
10 MW	34.7	21.3	25.3	15.0

Calculations are based on the following damage criteria:

Thermoplastic Cables: 400°F (325°F rise above ambient) and 0.5 BTU/ft^{2}sec

Thermoset Cables: 625°F (550°F rise above ambient) and 1 BTU/ft^{2}sec

The parameters of the zone of influence chart are also dependent on the fire location, and in particular, must be adjusted for fires located near a wall or corner. For the purposes of the phase 2 analysis, a fire is considered to be "near" a wall if its outer edge is within two feet of a wall, or is "near" a corner if within two feet of each of the two walls making up the corner.

For a fire located near a wall:

Table 2.3.3 - Calculated Values (in feet) for Use in the Ball and Column Zone of Influence Chart for Fires Adjacent to a Wall				
Fire HRR	**Thermoplastic Cables**		**Thermoset Cables**	
	H	**R**	**H**	**R**
70 kW	6.3	2.5	4.6	1.8
200 kW	9.6	4.3	7.0	3.0
650 kW	15.3	7.7	11.2	5.4
2 MW	24.1	13.5	17.5	9.5
10 MW	45.8	30.1	33.4	21.3

For a fire located near a corner:

Table 2.3.4 - Calculated Values (in feet) for Use in the Ball and Column Zone of Influence Chart for Fires Adjacent to a Corner				
Fire HRR	**Thermoplastic Cables**		**Thermoset Cables**	
	H	**R**	**H**	**R**
70 kW	8.3	3.6	6.1	2.5
200 kW	12.6	6.0	9.2	4.3
650 kW	20.3	10.8	14.8	7.7
2 MW	31.7	19.0	23.2	13.5
10 MW	60.4	42.5	44.1	30.1

NOTE: If the fire characteristics do not conform to those established for the 'simple' fire ignition source types (e.g., oil fires, revision to the transient fuel fire, etc.), it may be necessary to re-calculate the ball and column diagrams for a specific fire intensity value. In such cases, it is recommended that additional Agency fire PRA support be sought.

The screening of fire ignition sources is based on a check for damage or ignition targets within the zone of influence for a given fire source. If no such targets are within the zone of influence, the fire ignition source screens out.

As an alternative, a plume temperature correlation is described in detail in Chapter 9 of NUREG-1805. The **Plume_Temperature_Calculations.xls** spreadsheet can be used to calculate centerline temperature of a buoyant fire plume. Similarly, a correlation for estimating fire radiant heating effects is described in detail in Chapter 5 of NUREG-1805. Only the Wind Free Condition correlation (**Heat_Flux_Calculations_Wind_Free.xls**) is applied in the Phase 2 SDP process.

<u>Hot Gas Layer Temperature Analysis Correlation</u>
The correlation to be applied in the analysis of hot gas layer temperature response is documented in Chapter 2 of NUREG-1805. Depending on the ventilation mode, one of the following spreadsheets from NUREG-1805 will apply:

- Fire with Natural Ventilation: **Temperature_NV.xls** (Click on Thermally Thick Tab)
- Fire with Forced Ventilation: **Temperature_FV1.xls** (Click on Thermally Thick Tab)

In most cases, the "thermally thick" correlation will apply. Additional guidance is provided within the electronic spreadsheet.

Using the electronic spreadsheet, the predicted hot gas layer temperature will rise with increasing time. Screening should consider the temperature at 10 minutes. By this time, conditions will be approaching steady state.

The required inputs for use of the above correlations are described in detail in Section 2.11 of NUREG-1805, and are summarized as follows:

- Compartment width (ft)
- Compartment length (ft)
- Compartment height (ft)
- Select type of lining material from table
- Interior lining material thickness (in.)
- Fire heat release rate, HRR (kW)

When using the natural ventilation spreadsheet, the following values must also be obtained:

- Vent width (ft)
- Vent height (ft)
- Top of vent from floor (ft)

NOTE: A size of zero or very small ventilation openings should <u>*not*</u> *be applied with the hot gas correlation because the correlation does not consider the effects of oxygen starvation and, as a result, will provide erroneously high hot gas layer temperatures. The size of a standard door opening (3'0" x 6'8") should be applied as a default value for the natural ventilation case, with a larger opening applied, if appropriate.*

When using the forced ventilation spreadsheet, the following value must also be obtained:

- Forced ventilation rate (cfm)

NOTE: For the forced ventilation case, a minimum ventilation rate of one room air change per hour should be applied.

<u>Task 2.3.5: Screening Check</u>
This screening step considers whether or not one or more potentially challenging fire scenarios has been identified. If no such fire ignition source scenarios have been identified, then the finding screens to Green and the analysis is complete.

The screening criteria for this step are as follows:

- If <u>all</u> identified fire ignition sources screen out in Task 2.3.4, then no potentially challenging fire scenarios were developed. In this case, the Phase 2 analysis is complete and the finding should be assigned a Green significance determination rating. Subsequent analysis tasks and steps need not be completed.

- If one or more of the fire ignition sources is retained, even if only at the higher severity value, then the analysis continues to Step 2.4.

Step 2.4 - Fire Frequency for Unscreened Fire Sources

In Step 2.4, the fire frequency for each unscreened fire ignition source scenario (F_{Source}) is defined based on developed fire frequencies per counting unit for each ignition source multiplied by the unit counting performed in Task 2.3.1. The fire frequency for each unscreened fire ignition source is then further refined to reflect adjustments to findings within certain fire prevention and other administrative controls programs, and to take credit for compensatory measures, if appropriate.

Task 2.4.1: Nominal Fire Frequency Estimation

A frequency for each fire ignition source bin on a per component basis has been developed and is provided in Attachment 4. Using the counting results obtained in Task 2.3.4, record for each fire source, at its specified HRR values, the number of sources retained and the fire frequency per counting unit for each unscreened fire ignition source bin to obtain the fire frequency on a per ignition source basis.

Record the fire severity factor associated with each retained fire ignition source based on the screening results from Task 2.3.4. Severity factors are applied as follows:

- If a fire ignition source (or set of grouped fire ignition sources) was retained for both its expected and high confidence fire severity/HRR levels, then list the fire ignition source in the worksheet separately for each of the HRR levels, and apply a severity factor of 0.9 for the expected fire severity/HRR level and a severity factor of 0.1 for the high confidence fire severity/HRR level.
- If a fire ignition source (or set of grouped fire ignition sources) was retained only at its high confidence fire severity/HRR level, then a severity factor of 0.1 is applied.

Task 2.4.2: Findings Quantified Based on Increase in Fire Frequency

The fire frequency increase is only applicable to certain types of fire ignition sources; namely, hot work fires and transients:

- If the finding category assigned is anything other than “Fire Prevention and Administrative Controls,” no adjustment of the nominal fire frequencies is applied. The analysis continues with Task 2.4.3.

- Within the general category of “Fire Prevention and Administrative Controls” findings, only the inspection findings associated with any of the following fire protection DID elements will result in an increase in fire frequency:

    - Combustible controls programs,
        - For a fire area nominally ranked as a low or moderate likelihood for transient fires, the likelihood rating will be raised by one level of likelihood (i.e., a low likelihood area becomes a moderate area, and a moderate likelihood area becomes a high area) and the fire frequency is adjusted according to the revised likelihood fire frequency value.
        - For a fire area already ranked as a high likelihood area for transient fires, the high likelihood transient fire frequency is multiplied by a factor of 3.

    - Hot work permitting and/or hot work fire watch provisions of the fire protection program,
        - The fire area hot work fire likelihood is set to high, and the hot work fire frequency for high likelihood is multiplied by a factor of 3.

- If a finding within the general category of "Fire Prevention and Administrative Controls" is not against any of the fire protection DID elements listed above, then no adjustment of the fire frequency is applied. The analysis continues with Task 2.4.3.

Record the appropriate changes to likelihood frequencies and adjustment factors in the Attachment 1 Worksheet, Table A1.5.

Task 2.4.3: Credit for Compensatory Measures that Reduce Fire Frequency

If any of the following compensatory measures are in place and credited with reducing the frequency of transient fuel or hot work fires for the fire area under analysis, assign a compensatory measures adjustment factor of 0.0 to the appropriate fire ignition source scenarios:

- For transient combustible fire frequency: A combustible control system exists with frequent surveillance patrols (at least once per shift) and a review of surveillance reports show no discovery of improperly stored combustibles. There must be no documented surveillance reports indicating improperly stored materials during the finding exposure period.
- For hot work fire frequency: The area has not been used for hot work as verified through a review of hot work permits issued. Review the hot work permits associated with these activities and confirm that no hot work occurred in the fire area under review during the finding exposure period.

Record the appropriate adjustment factor(s) in the Attachment 1 Worksheet, Table A1.5. If none of the above listed compensatory measures are active for the fire area under analysis, no adjustment to the fire frequency is needed. If either hot work or transient fuels can be shown to never exist in the fire area, no further development of the corresponding fire scenarios is required to complete the Phase 2 analysis.

Sum the revised fire frequencies over all identified fire ignition source scenarios to generate an updated estimate of the fire frequency for the fire area under review.

Multiply the updated estimate of the fire frequency for the fire area under review by the duration factor (from Task 1.4.1) and $CCDP_{2.1.2}$ or $CCDP_{2.1.3}$ to generate the change in CDF value ($\Delta CDF_{2.4}$). Record the $\Delta CDF_{2.4}$ value in the Attachment 1 Worksheet, at the bottom of Table A1.5.

Task 2.4.4: Screening Check

Compare the updated change in CDF value ($\Delta CDF_{2.4}$) with the values in Table 2.4.1 or A1.6 to determine whether or not the finding screens to Green without further analysis. The screening level depends on both the finding category and the assigned degradation rating.

Table 2.4.1 - Phase 2, Screening Step 4 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	**$\Delta CDF_{2.4}$ screening value**	
	Moderate Degradation	**High Degradation**
Fire Prevention and Administrative Controls	N/A	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5[1]	
Localized Cable or Component Protection	1E-5[1]	
Post-fire SSD	1E-6	

[1] This entry applies to both 'Moderate A' and 'Moderate B' findings against a fire barrier.

- If the value of $\Delta CDF_{2.4}$ is lower than the corresponding value in Table 2.4.1, then the finding Screens to Green, and the analysis is complete.
- If the value of $\Delta CDF_{2.4}$ exceeds the corresponding value in Table 2.4.1, then the analysis continues to Step 2.5.

Step 2.5 - Definition of Specific Fire Scenarios and Independent SSD Path Second Screening Assessment

In Step 2.5, specific fire growth and damage scenarios are defined and corresponding plant damage state scenarios are also defined. Once the plant damage states are defined, the designated post-fire SSD path originally identified in Step 2.1 is re-assessed for potential applicability on a scenario specific basis.

<u>Task 2.5.1: Identify Specific Fire Growth and Damage Scenarios (Fixed Ignition Sources)</u>
Identify one or more fire growth and damage scenarios for each unscreened fire ignition source scenario. The fire growth and damage scenarios will also reflect each applicable FDS being carried forward in the analysis process as identified in Step 2.2. For each identified damage target, a failure criteria and threshold is also assigned. The target sets are chosen to suit specific fire ignition source scenarios and each FDS of interest:

- Identify for FDS1 scenarios, any unprotected components or cables in the immediate vicinity of the fire ignition source (e.g., directly above or next to the fire ignition source). FDS1 scenarios will include damage to:
  - Any unprotected components or cables that are subject to heating either by the fire plume or direct radiant heating, or
  - Components and cables near the fire source that are protected by a highly degraded fire barrier that are subject to plume or direct radiant heating.

- Identify for FDS2 scenarios, any components or cables throughout the fire area that might be damaged by a fire initiated in a given fire ignition source. FDS2 fire scenarios will include damage to:

- All cables and components that would be damaged in the corresponding FDS1 fire scenario for the same fire ignition source (unprotected components and cables near the fire ignition source),
    - Components and cables near the fire source that are protected by a moderately degraded fire barrier,
    - Components and cables that are not near the fire source that are protected by a highly degraded fire barrier, or
    - Components and cables protected by a fire barrier with a fire endurance rating of less than one hour.

- Identify for FDS3 scenarios, targets both within the primary fire area and in any adjoining fire areas that may be affected given fire spread to an adjacent fire area. The FDS 3 fire scenarios include damage to:
    - Components and cables that would be damaged in the corresponding FDS1 and FDS2 fire scenarios for the same fire ignition source, or
    - Components and cables located in the adjacent fire area.

Specific guidance in support of this task is provided in Attachment 6.

<u>Task 2.5.2: Identify Specific Fire Growth and Damage Scenarios (Self-ignited Cable Fire, Transients. Hot Work)</u>
The frequency of a self-ignited cable fire, transients, or hot work occurring in a specific location is low, even if such fires are plausible. In most fire areas, fire risk will be dominated by fires involving other fixed fire ignitions sources, in large part because such fires are simply far more frequent. Hence, a defensible estimate of fire risk change can often be calculated without explicitly analyzing the self-ignited cable fire, transients, or hot work scenarios.

This subset of fire scenarios should only be analyzed when there is a specific set of post-fire safe shutdown cable damage targets that is not threatened by any fixed fire ignition source. This could occur under the following conditions:

- The fire area being analyzed contains no fixed ignition sources (e.g., a cable tunnel or cable spreading room with nothing but cables in it), <u>or</u>
- All of the fixed ignition sources that might have threatened the target cables were screened out in Step 2.3, <u>or</u>
- None of the fixed ignition sources is close enough to the target cables to cause ignition/damage.

Include specific analysis of self-ignited cable fire, transients, or hot work if and only if one or more of the above conditions is met. If none of the above conditions are met, do not analyze this subset of fire scenarios.

Weighting factors may apply to self-ignited cable fire, transient, and hot work sources to reflect the likelihood that the fire will occur in specific locations versus all plausible locations in the fire area. See Attachment 5 for additional details.

Task 2.5.3: Identify Specific Plant Damage State Scenarios

Translate the fire-induced component and cable damage that corresponds to a specific fire growth and damage scenario into a specific plant damage state scenario. The plant damage state scenario defines the functional impacts of component and cable failure on the plant systems (e.g., specific valve in system x fails closed or fails open; or a pump fails to start).

The following general rules apply in defining the plant damage state scenarios:

- Assume that systems/functions are lost unless it can be verified (e.g., using information provided by the licensee) that the system will survive the postulated fire scenario.
- In most cases, assume that the loss of a system component or cable will render that system unavailable. In some cases, it may be appropriate to determine whether or not a system function is partially degraded or involves unique failure modes.
- Identify any manual operator actions included in the licensee's post-fire SSD procedures. Credited manual actions will be evaluated in Step 2.8.
- Determine if any fire-specific circuit failure modes (e.g., spurious operation) should be considered.

Example 1: Loss of motive/power cables to a major system component, such as a motor driven pump, will be assumed to render that system nonfunctional and unrecoverable.

Example 2: Loss of motive power to some system components, such as a motor-operated valve, may leave the system nominally operational, but may render the normal control operations nonfunctional (e.g., the operators may be able to shut down the system, but would be otherwise unable to control or change its operating configuration using the normal controls). In this case, manual operation of the component might still be possible. The SDP Phase 2 analyses will only credit such manual actions if they are included in the plant fire response procedures.

Example 3: Failure of a control cable may lead to spurious actuation of a system if that system is impacted by a known circuit analysis issue.

Example 4: Loss of an instrument or indication signal may leave a system nominally functional, but might complicate operator actions related to that system.

Example 5: Loss of a specific control cable might lead either to a loss of function or spurious operation fault mode for the impacted system. This can lead to the identification of two distinct plant damage state scenarios arising from one fire growth and damage scenario.

Systems and functions that are not assumed lost due to fire will be credited in the assessment of plant post-fire SSD efforts in Step 2.8 whether or not they are designated Appendix R safe shutdown systems.

Example 6: The licensee has not included off-site power on the Appendix R post-fire Safe Shutdown equipment lists. However, the licensee has traced the components and cables associated with off-site power, and provided information that verifies that off-site power will not be compromised by fires in the fire area under analysis. In this case, the plant damage state scenario can assume the survival of off-site power.

Judgment is applied in establishing a reasonable confidence that a particular system or function will survive given fires in the fire area.

> Example 7a: It may be reasonable to assume the survival of off-site power given a fire in the service water intake structure unless the physical plant layout presents the potential that cable or equipment supporting the off-site power systems were routed through or housed within that location.
>
> Example 7b: It would be reasonable to assume off-site power would be lost given any fire in the switch yard or any fire involving the unit main or unit auxiliary transformers.

Task 2.5.4: Assess Fire Scenario-Specific SSD Path Independence
Re-evaluate, on a scenario specific basis, the potential for crediting the designated post-fire SSD path (originally identified in Step 2.1). The independence of this SSD path is re-evaluated in the context of the fire ignition source scenarios and the corresponding plant damage state scenarios as defined in Task 2.5.3.

> *NOTE: If the designated SSD path met the independence criteria of Step 2.1, then it has already been credited for all fire scenarios and there is no additional screening benefit to be gained in this Step. In this case, Tasks 2.5.4 and 2.5.5 are not performed and the original SSD path failure probability is carried forward to Steps 2.6 and 2.7 as a screening CCDP for all individual scenarios.*

The SSD success path can be credited on a scenario specific basis if all of the following criteria are met given a specific combination of a fire ignition source scenario, fire growth and damage scenario, and plant damage state scenario:

- The SSD success path to be credited must be identified and analyzed in the licensee's post-fire SSD analysis, must be supported by procedures covering plant response to fires in the designated fire area, and must not be potentially compromised by a known circuit analysis issue.
- Cables or components needed to ensure successful operation of the SSD success path must not be damaged given the postulated fire growth and damage scenario associated with a given fire scenario.
- The functionality of the SSD path must not be compromised given the postulated plant damage state associated with a given fire scenario.
- All operator actions required to support successful operation of the SSD success path must be feasible given the fire scenario being postulated.
    - Operator actions within the impacted fire area will not be considered feasible.
    - Operator actions in an adjacent fire area will not be considered feasible in the specific context of an FDS3 fire scenario that involves that same adjacent fire area.

Review each unique fire scenario being carried forward in the analysis against the above criteria. If the SSD success path meets all the above criteria, it will be credited on a fire scenario specific basis in subsequent steps using the same overall system unavailability factor as was determined in Task 2.1.2 ($CCDP_{2.1.2}$). If the SSD success path does not meet all of the above criteria on a scenario specific basis, the CCDP =1.0 for that scenario.

Example 1: If a FDS1 fire scenario involves damage to only one train of plant safety equipment, and the designated SSD path relies on an undamaged redundant train of plant safety equipment, the survival of the SSD path can be credited for that FDS1 scenario even if the cables for the redundant train are also located in the impacted fire area.

Example 2: As an extension of Example 1, a FDS2 fire scenario is defined involving damage to both equipment trains. In this case, the SSD path might survive given an FDS1 scenario, but would fail given an FDS2 or FDS3 scenario.

Task 2.5.5: Screening Check

Perform a quantitative screening check to determine whether the SSD path can be credited for all fire scenarios arising from a given fire ignition source scenario on a bounding basis for each fire ignition source. To accomplish this screening check:

- Identify for each fire ignition source the worst-case plant damage state in descending order of damage by considering the FDS3, then the FDS2, and then the FDS1 scenarios as applicable to a given fire ignition source.
- If the designated SSD path was deemed independent of the worst-case FDS scenario for a given fire ignition source, then the designated SSD path is credited for all fire scenarios involving that fire ignition source.
- If the SSD path cannot be credited for the any of the identified fire ignition sources given the worst-case damage state, then Step 2.5.5 is complete, and the analysis continues with Step 2.6 (i.e., $\Delta CDF_{2.5} = \Delta CDF_{2.4}$).
- If the SSD path can be credited for at least one fire ignition source given its worst-case damage state:
    - For those fire ignition sources where the designated SSD path is to be credited, multiply the revised fire frequencies (from Step 2.4) by the $CCDP_{2.1.2}$ (from Task 2.1.2).
    - For those fire ignition sources where the designated SSD path is <u>not</u> to be credited, multiply the revised fire frequencies (from Step 2.4) by the $CCDP_{2.1.3}$ (from Task 2.1.3).
    - Sum the updated values for all of the fire ignition sources for the fire area under review.
    - Multiply the new summed value for the fire area under review by the duration factor (from Task 1.4.1) to generate the change in CDF value ($\Delta CDF_{2.5}$). Record the $\Delta CDF_{2.5}$ value in the Attachment 1 Worksheet at the bottom of Table A1.7.
    - Perform a screening check based on the values and criteria provided in Table 2.5.1 or A1.8. The screening level depends on both the finding category and the assigned degradation rating.

Table 2.5.1 - Phase 2, Screening Step 5 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	**$\Delta CDF_{2.5}$ screening value**	
	Moderate Degradation	**High Degradation**
Fire Prevention and Administrative Controls	N/A	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5[1]	
Localized Cable or Component Protection	1E-5[1]	
Post-fire SSD	1E-6	

[1] This entry applies to both 'Moderate A' and 'Moderate B' findings against a fire barrier.

- If the value of $\Delta CDF_{2.5}$ is lower than the corresponding value in Table 2.5.1, then the finding screens to Green, and the analysis is complete.
- If the value of $\Delta CDF_{2.5}$ exceeds the corresponding value in Table 2.5.1, then the analysis continues to Step 2.6.

Step 2.6 - Fire Growth and Damage Scenario Time Analysis

In Step 2.6, the fire behavior for unscreened fire scenarios are analyzed in order to estimate the time to reach a particular, relevant FDS. All damage times will be recorded to the nearest whole minute rounded down.

Specific guidance supporting Step 2.6 is provided in Attachment 7.

<u>Task 2.6.1: Fire Growth and Damage Time Analysis - FDS1 Scenarios</u>
For FDS1, two fire damage mechanisms are considered; namely, fire plume effects (including direct flame impingement), and direct radiant heating. Included in the timing analysis is consideration of fire spread to secondary combustibles if such fire spread is required to create the damaging exposure conditions.

- First, predict the exposure conditions for the damage target(s) using the NRC Fire Dynamics Tools:
  - Determine the target exposure conditions for plume temperature and/or a radiant heat flux depending on the location of the target relative to the fire.
  - With the calculated estimate of exposure temperature and/or heat flux, estimate the time to damage using Tables A7.1 thru A7.4 provided in Attachment 7.
- For some scenarios, the spread of fire to secondary combustibles (typically cables) near the fire source is required to create damaging exposure conditions at the location of the target. In such cases, the damage time will include the time required for critical fire spread. Rules for the development of the cable tray fire scenario are contained in Attachment 3.

Task 2.6.2: Fire Growth and Damage Time Analysis - FDS2 Scenarios

FDS2 involves widespread damage to targets located within the fire area including damage to components protected by a degraded fire barrier system. FDS2 scenarios involve FDS1 level damage plus additional damage in a wider portion of the fire area.

- The analysis of FDS2 scenarios involves elements similar to those for FDS1; namely, plume and direct radiant heating exposures combined with localized fire spread.
  - If a specific fire ignition source has been analyzed for an FDS1 scenario, carry the resulting time to damage results for targets near the fire source forward to the FDS2 scenario.
  - If a specific fire ignition source has not been analyzed for an FDS1 scenario, predict the time to damage for targets near the fire source using the fire modeling tools as described in Task 2.6.1.

- Evaluate hot gas layer effects for the FDS2 scenarios:
  - The hot gas layer temperature is estimated using a correlation described in Task 2.3.4.
    - Start with the HRR of the fire ignition source
    - If the hot gas layer temperature at 10 minutes is greater than or equal to the damage threshold, then the ignition source alone is enough to cause damage.
  - If the hot gas layer exceeds the damage threshold, estimate the time to damage using Tables A7.1 or A7.2 provided in Attachment 7.
  - If spread of the fire to secondary combustibles (typically cables) is critical to creating a damaging hot gas layer, increase the fire size in the fire dynamics tools (FDT), in steps of 50kW increments, until the temperature at 10 minutes reaches the damage threshold and record the required HRR.
  - Determine how far the fire must spread to create a fire of the required HRR.
    - Cable trays are assumed to burn at 400kW/m^2
    - Calculate the square feet of cable try required to get the fire size needed
    - Ignition source is burning - trays only have to make up the difference
  - Determine if there are enough trays to get a fire this critical level
    - If not, the FDS2 scenario is not credible
    - If yes, estimate the time required to spread the fire to the critical level. Additional guidance is provided in Attachment 3.

- Evaluate the potential for damage due directly to the spread of fire beyond the immediate vicinity of the fire ignition source for the FDS2 scenarios:
  - In such cases, construct a fire spread pattern and determine the time required to spread the fire to the critical target location(s).

- Evaluate the potential failure of components that are protected by a moderately degraded fire barrier system for the FDS2 scenarios:
  - For such findings, the performance time of the fire barrier system is reduced to reflect the noted deficiency. Additional guidance is provided in Attachment 7.
  - Determine the time to damage based on: (1) establishing the time for a potentially damaging exposure condition (temperature and/or heat flux) and (2) the degraded fire barrier performance time.

Task 2.6.3: Fire Growth and Damage Time Analysis - FDS3 Scenarios

FDS3 involves fire spread through an inter-compartment fire barrier element (e.g., penetration seal, door, or damper). For the purposes of this FP SDP, “inter-comparment” shall be interpreted as a boundary between fire areas. If the barrier element itself is the finding (i.e., the barrier is degraded - a fire confinement finding), then the fundamental objective is to assess the likelihood of fire spread between two (or more) fire areas. These scenarios build upon the fire endurance rating of the fire barrier. The scope of the analysis depends in part on the nature of the finding:

- If the finding is not associated with a degraded inter-compartment fire barrier element, then the focus is placed on fires within the fire area under analysis that may spread to any adjacent fire area.
- If the finding is associated with a degraded inter-compartment fire barrier, then the focus is placed on fires involving the two fire areas that are separated by the degraded barrier element. Degradation of the barrier element will be reflected as a reduced performance time. Both, fires within the fire area under analysis that may spread to the adjacent fire area, and fires in the adjacent fire area that might spread into the fire area under analysis must be considered.

Step 2.7 - Non-Suppression Probability Analysis

In Step 2.7, the Probability of Non-Suppression for each fire growth and damage scenario of interest (PNSi) is quantified. Detailed guidance on this step is provided in Attachment 8. All detection/suppression times will be recorded to the nearest whole minute rounded up.

Task 2.7.1: Fire Detection

The fire detection analysis considers the possibility of detection by any one of the following mechanisms:

- Prompt detection by a posted and continuous fire watch ($t_{detection} = t_{ignition} = 0$, if general rules in Attachment 8 are met)
- Detection by a roving fire watch (½ the duration of the roving patrol),
- Detection by fixed fire detection systems, and
- Detection by general plant personnel ($t_{detection}$ = 5 minutes if fire area is continuously manned; otherwise $t_{detection}$ = 15 minutes absent detection by other means)

Only one of the above means of detection is need to succeed in order for the fire to be detected. The first and/or most likely mechanism of detection is generally credited.

Estimate the time to fire detection by using the guidance in Attachment 8. These analyses require the use of the fire modeling correlations contained in NUREG-1805. This time is important because it triggers other human performance actions such as manual control actions and activation of the manual fire brigade.

Detection by a Fixed Detection System

If a fire area is covered by a fixed fire detection system, but is not covered by a continuous fire watch, then the response time of the fixed system will be assumed to dominate the overall fire detection time. Fire detection response time is estimated using the NRC Fire Dynamics Tools in NUREG-1805:

- Smoke Detector Activation Time: **Detector_Activation_Time.xls** (Click on Smoke Tab)
- Heat Detector Activation Time: **Detector_Activation_Time.xls** (Click on FTHDetector Tab)

These correlations are described in detail in Chapters 11 and 12 of NUREG-1805, respectively. Inputs required for use of the correlation are also described in detail in the NUREG, and are summarized as follows:

- For smoke detectors:
    - heat release rate of the fire (kW)
    - ceiling height of the compartment (ft)
    - radial distance from the centerline of the plume (ft)

- For heat detectors:
    - heat release rate of the fire (kW)
    - radial distance to the detector (ft)
    - listed spacing of detectors (ft)
    - activation temperature of detectors (°F)
    - distance from the origin to ceiling (ft) *[This is a deviation from NUREG-1805.]*
    - ambient room temperature (°F)

The correlation will provide detector activation time in seconds. Convert this value to minutes, rounding up to the nearest minute. The spreadsheets may indicate that time to detection is infinite (i.e., the system will not actuate). In this case, the time to detection is determined by the other means of fire detection available including detection by plant personnel.

<u>Task 2.7.2: Fixed Fire Suppression System Analysis</u>
Assess the performance and actuation timing of fixed fire suppression systems and any findings against a fixed fire suppression system.

> *NOTE: If the fire area under analysis is not equipped with a fixed fire suppression system or the fixed fire suppression system has been found to be highly degraded, skip Task 2.7.2 and continue the analysis with Task 2.7.3.*

Both automatically-actuated and manually-actuated fixed fire suppression systems will be considered in this task. Two key factors to the fixed suppression assessment are:

- <u>Effectiveness</u>: If the fixed suppression system actuates, will it control a fire involving the postulated fire ignition source?
- <u>Timing</u>: When will the system discharge the fire suppressant?

If the suppression system is deemed effective, then its actuation will be assumed to disrupt the fire scenario and prevent further fire damage thereby ending the fire scenario.

There are a number of time delays that may apply to gaseous systems, deluge, pre-action sprinklers, or dry-pipe water systems. The time to actual discharge is the sum of the time to actuate the demand signal plus any applicable discharge timing delays. There may also be a delay for cross zoned detection system, i.e., the automatic suppression system will not begin actuation sequence until after the second detector is actuated. If cross-zoning is used, the detection time analysis should be reviewed to ensure that the cross-zone detection criteria are met. The time to generation of the actuation signal will be dominated by the slower detector (typically the detector farther from the fire ignition source). Additional guidance is provided in Attachment 8.

Activation Time for Sprinkler Systems
The correlation for estimating sprinkler activation time is described in detail in Chapter 10 of NUREG-1805. The following spreadsheet is used:

- **Detector_Activation_Time.xls** (Click on Sprinkler Tab)

Inputs for calculating sprinkler activation time are described in Section 10.5 of NUREG-1805 and are summarized as follows:
- Heat release rate of the fire (kW)
- Activation temperature of the sprinkler (°F)
- Distance from the origin to ceiling (ft) *[This is a deviation from NUREG-1805.]*
- Radial distance from plume centerline to sprinkler (ft)
- Ambient air temperature (°F)
- Sprinkler type

The correlation will provide sprinkler activation time in seconds. Convert this value to minutes, rounding up to the nearest minute. The spreadsheet may indicate that time to detection is infinite (i.e., the system will not actuate). In this case, no credit is given to the fixed fire suppression system.

If the finding being evaluated involves a moderate degradation to the sprinkler system, credit is given to the system consistent with the as-found condition. The finding may be reflected either as a reduction in general reliability, or through a delayed actuation time. The treatment depends on the nature of the finding as follows:

- If the findings is associated with improper spacing of discharge heads, the actuation timing analysis should reflect the as-found spacing conditions.

- A moderate degradation may involve less than 25% of the heads in a water-based fire suppression system being non-functional. In this case, analyze discharge timing assuming that the head nearest the fire source will not function. Assume that the second closest fire discharge nozzle will function. Use the location of this second closest discharge nozzle in estimating response time.

- A moderate degradation finding may imply that the fire suppression system does not provide adequate coverage for some specific subset of the fire ignition sources present. In this case the fire suppression system is not credited in the analysis of FDS1 fire scenarios involving those specific fire ignition sources. The system is credited in the analysis of corresponding FDS2 and FDS3 scenarios and performance is analyzed consistent with the as found conditions.

If the fixed fire suppression system is manually actuated, the time to actuation will be based on the estimated fire brigade response time, plus a nominal period of two minutes to assess the fire situation and actuate the system.

Task 2.7.3: Plant Personnel and the Manual Fire Brigade

Evaluate the timing associated with manual fire suppression. The manual fire fighting response time is based on the application of historical evidence from past fire events. Based on this historical evidence, non-suppression probability curve values have been pre-calculated for a number of cases. Select the most representative case from the pre-analyzed set based on the fire type or location. If none of these specific condition curves provide a reasonable match to the conditions of the fire scenario, the "all events" curve should be applied. The mean non-suppression probability curves for each of these fire types/locations are provided in Attachment 8.

1. All events
2. Hot work (welding) fires
3. Transient fires
4. Electrical fires
5. Cable fires
6. Transformer/switchyard
7. Main Control Room
8. Turbine Generator
9. Energetic Arcing Faults
10. Containment fires (non-inerted containments)

For each unscreened fire scenario, subtract the fire detection time determined in Task 2.7.1 from the fire damage time determined in Step 2.6.

- If the fire detection time subtracted from the fire damage time is zero or negative, then PNS_{manual} = 1.0.
- If the fire detection time subtracted from the fire damage time is positive, enter the left hand column of the PNS_{manual} table on the following page with this calculated value and read across to the appropriate fire type category. This intersection provides the mean non-suppression value for manual fire fighting.

The assessment is repeated for each unscreened fire scenario.

As an alternative, the PNS_{manual} value can be calculated using the following formula:

$$PNS_{manual} = \exp[-\lambda \times t]$$

Where 'λ' is the mean rate constant (1/min) for the given fire type and 't' is the fire duration time (time to damage after detection) in minutes. The values for 'λ' for each of the ten fire type/location categories are provided in the last row of the PNS_{manual} table.

Table 2.7.1 - Non-suppression Probability Values for Manual Fire Fighting Based on Fire Duration (Time to Damage after Detection) and Fire Type Category										
$T_{Damage} - T_{Detection}$ (min)	Mean manual non-suppression probability curve values - PNS_{manual}									
	All Events	Hot Work - Welding	Transients	Electrical Fires	Cable Fires	Switchyard	Main Control Room	Turbine Generator	Energetic Arcing Faults	Containment
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	0.93	0.93	0.87	0.89	0.84	0.97	0.78	0.98	0.95	0.94
2	0.87	0.86	0.76	0.79	0.70	0.95	0.62	0.96	0.90	0.89
3	0.81	0.80	0.66	0.70	0.59	0.92	0.48	0.94	0.86	0.84
4	0.76	0.74	0.58	0.63	0.49	0.90	0.38	0.92	0.81	0.80
5	0.71	0.69	0.51	0.56	0.41	0.88	0.30	0.90	0.77	0.75
6	0.66	0.64	0.44	0.50	0.35	0.85	0.23	0.88	0.74	0.71
7	0.62	0.59	0.38	0.44	0.29	0.83	0.18	0.86	0.70	0.67
8	0.58	0.55	0.34	0.39	0.24	0.81	0.14	0.84	0.66	0.63
9	0.54	0.51	0.29	0.35	0.20	0.79	0.11	0.83	0.63	0.60
10	0.50	0.47	0.26	0.31	0.17	0.77	0.09	0.81	0.60	0.57
12	0.44	0.41	0.19	0.25	0.12	0.73	0.05	0.78	0.54	0.51
14	0.38	0.35	0.15	0.20	0.08	0.69	0.03	0.74	0.49	0.45
16	0.33	0.30	0.11	0.15	0.06	0.66	0.02	0.71	0.44	0.40
18	0.29	0.26	0.09	0.12	0.042	0.62	0.013	0.68	0.40	0.36
20	0.25	0.22	0.07	0.10	0.029	0.59	0.008	0.65	0.36	0.32
25	0.18	0.15	0.03	0.05	0.012	0.52	0.002	0.59	0.28	0.24
30	0.13	0.11	0.017	0.03	0.005	0.46	0.001	0.53	0.21	0.18
35	0.09	0.07	0.008	0.017	0.002	0.40	*	0.48	0.17	0.14
40	0.06	0.05	0.004	0.009	0.001	0.35	*	0.43	0.13	0.10
45	0.05	0.03	0.002	0.005	*	0.31	*	0.39	0.10	0.08
50	0.03	0.02	0.001	0.003	*	0.27	*	0.35	0.08	0.06
55	0.02	0.02	*	0.002	*	0.24	*	0.31	0.06	0.04
60	0.02	0.01	*	0.001	*	0.21	*	0.28	0.05	0.03
* Value is less than 0.001. Screen using PNS_{manual}=0.001 or use formula to calculate actual value.										
Mean Rate Constant (1/min)	0.069	0.075	0.137	0.117	0.177	0.026	0.242	0.021	0.051	0.057

Manual fire fighting non-suppression curves are also provided in Attachment 8. These curves provide the same results as the PNS_{manual} table, but can be used as follows:

- If the fire detection time subtracted from the fire damage time is zero or negative, then PNS_{manual} = 1.0.

- If the fire detection time subtracted from the fire damage time is positive, then:
    - Enter the appropriate fire duration curve and read across the x-axis to this calculated time difference value.
    - Transfer up to the corresponding point of the fire duration curve, and read across to the left to estimate the PNS_{manual}.

<u>Task 2.7.4: Probability of Non-Suppression</u>
Using the information gathered in Step 2.6 with the results of the completed tasks in Step 2.7, estimate the likelihood that fire suppression efforts fail to suppress the fire before the FDS state is reached - the probability of non-suppression (PNS). PNS is assessed on a scenario-specific basis.

The method applied to quantify PNS depends on whether or not a fixed fire suppression is being credited:

- For cases where fixed fire suppression systems are not being credited, PNS is based entirely on the response of the manual fire brigade compared to the predicted damage time.
- For fire areas protected by fixed suppression (either automatic or manually actuated), two suppression paths are considered: success of the fixed suppression system; and failure of the fixed suppression system to actuate on demand combined with the response of the manual fire brigade.

<u>Fixed Suppression System: $PNS_{fixed\text{-}scenario}$</u>
If the fire area is protected by fixed fire suppression, estimate PNS_{fixed} for each surviving scenario ($PNS_{fixed\text{-}scenario}$) for which the fire suppression system is deemed effective. A look-up table is provided in Attachment 8, and a $PNS_{fixed\text{-}scenario}$ is assigned based on the difference between the predicted time to fire damage (from Step 2.6) and the predicted time to suppression system actuation (from Task 2.7.2).

Calculate an estimate of $PNS_{fixed\text{-}scenario}$ for each unscreened fire scenario based on the scenario-specific fire damage and fire suppression times. Record PNS_{fixed} on the Attachment 1 Worksheet, Table A1.10.

<u>Manual Fire Suppression: $PNS_{manual\text{-}scenario}$</u>
The value of PNS_{manual} for a given scenario ($PNS_{manual\text{-}scenario}$) is dependent on three factors: the predicted time to fire damage (Step 2.6), the predicted time to fire detection (Task 2.7.1), and the selected fire duration curve (Task 2.7.3). Record PNS_{manual} on the Attachment 1 Worksheet, Table A1.10.

<u>Composite Suppression Factor: $PNS_{scenario}$</u>
If the fire area is not covered by fixed fire suppression, or is highly degraded, or is determined to be ineffective for the fire ignition source, then:

$$PNS_{scenario} = PNS_{manual\text{-}scenario}$$

If the fire area is covered by non-degraded wet-pipe sprinklers, a general reliability of 0.98 is assumed for the fixed suppression system. In this case, the PNS is quantified as follows:

$$PNS_{scenario} = (0.98 \text{ x } PNS_{fixed\text{-}scenario}) + (0.02 \times PNS_{manual\text{-}scenario})$$

If the fire area is covered by a non-degraded dry-pipe sprinklers or deluge system, or by a non-degraded gaseous suppression system, a general reliability of 0.95 is assumed for the fixed suppression system. In this case, the PNS is quantified as follows:

$$PNS_{scenario} = (0.95 \times PNS_{fixed\text{-}scenario}) + (0.05 \times PNS_{manual\text{-}scenario})$$

One specific type of degradation that may be identified for a gaseous fire extinguishment systems involves the inability of the system to maintain the design concentration of fire suppressant for a sufficient time to assure the complete extinguishment of a deep-seated fire. The required suppressant concentration and maintenance time are established by the system design criteria. This degradation is commonly referred to as an “inadequate soak time.” This can be an issue for Halon and Carbon Dioxide fire extinguishment systems, as well as for other gaseous suppression systems (e.g., Halon replacements).

For the inadequate soak time degradation case, special consideration is required to estimate $PNS_{scenario}$. See Attachment 8 for guidance on calculating $PNS_{scenario}$ involving gaseous fire extinguishment systems that are unable to maintain the design concentration of fire suppressant for a sufficient time to assure the complete extinguishment of a deep-seated fire.

<u>Task 2.7.5: Screening Check</u>
In Task 2.7.5, a screening check is made that considers the non-suppression probability for each fire scenario with the factors considered in previous screening checks.

The estimated risk contribution or screening CDF, for each fire scenario is based on the product of the following factors:

$$\Delta CDF_{2.7} \approx DF \text{ x } \Sigma\left[F_{Source} \text{ x } SF_{Source} \text{ x } \Pi AF_{Source\ 2.4} \text{ x } PNS_{Scenario} \text{ x } CCDP_{Scenario}\right]_{All\ Scenarios}$$

If $\Delta CDF_{2.7}$ is less than or equal to 1E-6, then the finding screens to Green, and the analysis is complete. If $\Delta CDF_{2.7}$ is greater than 1E-6, then the analysis continues to Step 2.8.

Step 2.8 - Plant Safe Shutdown Response Analysis

In Step 2.8, the plant SSD response, including required human recovery actions, is analyzed and the factor “$CCDP_i$“ for each fire growth and damage scenario of interest is quantified.

<u>Task 2.8.1: Select Plant Initiating Event Worksheets</u>
Identify which plant initiating event worksheet(s) in the plant risk-informed inspection notebook will be used to assess the fire scenario CCDP. One or more of these worksheets may be selected to represent the fire-induced SSD challenge. Typically, only one worksheet will be used, corresponding to the initiating event whose characteristics most closely resemble the impact of the fire on the plant. However, if there is a possibility of a spurious actuation that would change the nature of the event, e.g., changing a transient into a LOCA, more than one worksheet may be need to be used. The following general rules apply to the selection of the appropriate initiating event worksheets:

- If it cannot be assured that cables associated with offsite power distribution will not be affected by the fire, the assumption is that offsite power is lost. Use the loss of offsite power (LOOP) initiating event worksheet. If the fire response procedures are such that the plant is effectively put into a station blackout (i.e., a self-induced station blackout), use the LOOP worksheet.
- If offsite power is known not to be lost, and it cannot be assured that the power conversion system is available, use the transient without power conversion system (TPCS) initiating event worksheet.
- If neither offsite power nor the power conversion system is lost, use the general transient (TRANS) initiating event worksheet.
- If a small LOCA is possible(e.g., RCP seal failure), use the small LOCA (SLOCA) initiating event worksheet.
- If a stuck open safety/relief valve is possible, use the stuck open relief valve (SORV) initiating event worksheet.

Task 2.8.2: Identify Credited Systems and Functions

Identify those systems and functions that can be credited as available to support plant SSD response for each fire damage state scenario and initiating event of interest.

The following considerations are important to determining whether or not systems and functions should be credited in a fire scenario analysis:

- Ensure that the credited systems and functions actually be available given the postulated fire scenario. The event sequence models in the plant risk-informed inspection notebooks typically credit systems and functions not credited in the licensee's post-fire SSD analysis. In the fire protection SDP context, it is appropriate to credit all available systems and functions whether or not they are credited in the post-fire SSD analysis. However, it is not appropriate to credit the full complement of equipment associated with the plant systems and functions included in the internal event models unless it can be determined, with reasonable confidence, that they will in fact survive the fire scenario.
- System/functional loss or survival depends on the actual location of components and cables related to that system or function. The ability to credit systems and functions is largely dependent on the licensee's state of knowledge regarding cable and component routing within the plant. A significant amount of time is not expected to be spent verifying equipment or cable routing within any fire area. Use the routing information provided by the licensee. In the absence of such routing information within a fire area, unverified systems and functions are assumed to fail.
- Circuit problems may result in spurious actuation of SSCs, leading to failure of required functions.

Task 2.8.3: Identify Ex-Control Room Manual Actions

Identify manual actions included in the SSD procedures in response to a given fire scenario. The ex-control room manual actions of interest include manual actions introduced to prevent spurious actuations and manual actions required for manual control of systems. The SSD procedures may also include procedural directions to abandon the control room in favor of using the remote shutdown panel.

Task 2.8.4: Assess the Failure Probability of Manual Actions

Assess the failure probability of manual action identified above by using the following guidance:

- For operator actions already incorporated in the internal event worksheets that are performed in the control room or are performed outside the control room but are unaffected by the fire by either spacial or temporal considerations, use the human error probabilities (HEPs) documented in the notebooks, even though it is recognized that there may be additional negative performance shaping factors on human performance given a fire.
- For ex-control room manual actions not contained in the internal event worksheets, use the tables on the following pages. Table 2.8.1 is for manual actions in a remote location; Table 2.8.2 is for manual actions at the remote shutdown panel. The general process for reviewing manual actions will be :
    - Review each Category, and its Task and Scenario Characteristics with any additional Performance Shaping Factors to determine if it is applicable to the manual action being evaluated.
    - For each that applies, record the evaluation value (i.e., α, β, 2β, or γ)
    - Sum the evaluation factors and apply the following rules sequentially in order to determine the value assigned to the HEP for that manual action, with one exception - if time is expansive, go to next bullet (○).
        - If any row is α, then use a credit of 0.
        - If the sum of rows evaluated as β or 2β is $\geq 3\beta$, then assume it is equivalent to α and use a credit of 0.
        - If all categories are γ, the use a credit of 2.
        - Otherwise, use a credit of 1.
    - If the time available is evaluated to be expansive, sum the remaining evaluation factors (other than time) and apply the following rules sequentially in order to determine the value assigned to the HEP for that manual action:
        - If any row is α, or the sum of the βs $>3\beta$, use a credit of 0.
        - If the sum of the βs $= 3\beta$, use a credit of 1.
        - If the sum of the βs $\leq 2\beta$, use a credit of 2.
    - Repeat the review for each defined manual action within the scenario.

Table 2.8.1 - Manual Actions Evaluation Table for Actions at a Remote Location				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Direct Physical Effect of Fire (Ergonomics)	Location and fire area well separated			γ
		Operator must pass through areas affected by fire environment to reach location		2β
	No barrier or potentially significant leakage between location and fire area	Dense smoke, high temperature, and/or CO_2 impact in location	No credit for SCBAs	α
Functional Considerations (Ergonomics)	Accessibility restricted, e.g., a ladder, or special tool required	Tools properly staged		γ
		Tools must be brought in		β
	Lighting failed	Emergency lighting available		γ
		Only flashlights available		β
		Neither emergency lighting nor flashlights available		α
Procedures	Procedures specific to this activity	Procedures posted at the location, and all required actions addressed and achievable at location		γ
		Must be obtained from control room	Adjust to β if time is limited	γ/β
	No specific procedure OR procedure unclear			2β
Training/Experience	Realistic training on scenario			γ
	Little or no hands-on (vice desktop) training			β
Communications (Ergonomics)	Performance of task requires communication between operator and control room (or an operator at another location)	Communication unhindered by noise, interference		γ
		Communication difficult because of fire or location (noise, lighting, etc.)		β

Table 2.8.1 - Manual Actions Evaluation Table for Actions at a Remote Location				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Nature of Task (Complexity)	Simple task involving a change of state of an SSC			γ
	task requiring several subtasks, but all in the same general location	Procedures available and clear		γ
	Multiple tasks at different locations		In the absence of an RSP for example, it is assumed that several tasks are performed at diverse locations, requiring a significant degree of coordination.	2β
	Control task (e.g., maintaining AFW)	Indications available locally		β
		Indications not available locally		2β
Time available	Time Adequate to reach location and perform activity		Include time needed to obtain procedure if applicable	γ
	Time limited			β
	Time inadequate or barely adequate			α
	Time expansive			Note 1

Select HEP credit based on the following rules:

- If any row is α, then use 0
- If the sum of rows evaluated as β or 2 β is ≥ 3 β, then assume equivalent to α and use 0
- If all categories are γ, then use a credit of 2
- Otherwise (i.e., if the sum of rows evaluated as β or 2 β is β or 2 β), then use a credit of 1

Note 1: If sum of the other ratings is ≥α or >3β, use 0; if the sum is 3β, use a credit of 1; if the sum is ≤ 2β, use a credit of 2

Table 2.8.2 - Manual Actions Evaluation Table for Actions at Remote Shutdown Panel				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Direct Physical Effect of Fire (Ergonomics)	RSO and all areas where local actions take place are well separated from the fire location			γ
		Operator must pass through areas affected by fire environment to reach RSO or other areas where local actions are taken		2β
	No barrier or potentially significant leakage between RSO or other required locations and fire area	Dense smoke, high temperature, and/or CO_2 impact in location	No credit for SCBAs	α
Functional Considerations (Ergonomics)	Lighting failed at any required location	Emergency lighting available		γ
		Only flashlights available		β
		Neither emergency lighting nor flashlights available		α
	Local actions required for essential functions	All equipment accessible		γ
		Accessibility limited		β
		Not accessible		α
Procedures	RSO procedure	Procedures available at RSO panel and all necessary location, and all required actions addressed		γ
		Must be obtained from control room or RSO location	Adjust to β if time is limited	γ/β
Training/Experience	Realistic training on scenario			γ
	Little or no hands-on (vice desktop) training			β

Table 2.8.2 - Manual Actions Evaluation Table for Actions at Remote Shutdown Panel				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Nature of Task (Complexity)	Control task (e.g., maintaining AFW)	Indications available locally		β
		Indications not available locally	Requires gaining information from operators stationed throughout the plant. Communications good.	β
			Requires gaining information from operators stationed throughout the plant. Communications problematic.	2β
Time available	Time Adequate to reach location and perform activity		Include time needed to obtain procedure if applicable	γ
	Time limited			β
	Time inadequate or barely adequate			α
	Time expansive			Note 1
Select HEP credit based on the following rules: • If any row is α, then use 0 • If the sum of rows evaluated as β or 2 β is ≥ 3 β, then assume equivalent to α and use 0 • If all categories are γ, then use 2 • Otherwise (i.e., if the sum of rows evaluated as β or 2 β is β or 2 β), then use 1 Note 1: If sum of the other ratings is ≥α or >3β, use 0; if the sum is 3β, use a credit of 1; if the sum is ≤ 2β, use a credit of 2				

Use the most limiting of the factors (e.g., if the local actions that are essential to success are in inaccessible places, use α).

Task 2.8.5: Assess the CCDP

Assess the $CCDP_i$ for each fire scenario by using the plant risk-informed inspection notebook to: (1) incorporate failure of those systems and functions that will not be credited for the initiating event identified, and (2) incorporate human error probabilities for manual actions.

For each fire damage state scenario, calculate $CCDP_i$, using the applicable initiating event worksheet as follows:

- Set the initiating event frequency to 0.
- Reduce the credit for each mitigating system function commensurate with the systems and functions available to support the plant SSD.

  Example: The internal initiating event worksheet indicates that one of two trains for a given safety function is needed to provide full creditable mitigation capability. With both trains available, a multi-train system credit of 3 is assigned. If in the fire damage state scenario only one of the two trains for that safety function is protected, the credit is reduced from a multi-train credit of 3 to a single train credit of 2 because the unprotected train is assumed to fail in the fire scenario.

- Incorporate the impact of the human error contribution.
  - When a normally automatic function is required to be performed manually, compare the credit for the manual action as determined in Task 2.8.4 with the mitigation system credit provided for that safety function in the internal worksheet, and apply the more conservative of the two credits.
  - For actions performed in accordance with fire response procedures, identify the function(s) with which they are associated, and compare the manual credit with the hardware credit, and use the more conservative.
  - For compensatory manual actions in procedures that are included specifically to prevent a spurious actuation of equipment, a different initiating event worksheet may be required, or different assessments on the same worksheet may be required depending on the consequences of the preventive action and the spurious actuation:
    - When the preventive action is successful, additional equipment over and above that made unavailable by the fire may have been disabled and this should be taken into account when quantifying the worksheet.
    - Failure to perform that action (using Task 2.8.4), may make additional equipment available because it was not disabled by procedure, but it will also result in spurious actuations with a specified probability. The $CCDP_i$ needs to be evaluated for both cases: spurious actuations occur, and spurious actuations do not occur. The consequence of the spurious actuation may result in a need to use an additional worksheet, or may result in the failure of one of the functions on the original worksheet. For the case where the spurious actuation does not occur, the original worksheet will be used taking into account only the failures caused by the fire scenario.

- The total $CCDP_i$ is a weighted sum of the three CCDPs corresponding to the following:

$$
\begin{aligned}
CCDP_i = {} & [(1-HEP_i) \times CCDP(\text{given successful manual action})] + \\
& [HEP_i \times P_{SPi} \times CCDP(\text{given manual action fails and spurious actuation})] + \\
& [HEP_i \times (1 - P_{SPi}) \times CCDP(\text{given manual action fails and no spurious actuation})]
\end{aligned}
$$

where: HEP_i is the true value of the human error probability for scenario i (not the exponent value derived from the HEP tables), and
P_{SPi} is the probability of a spurious actuation for scenario i.

Table 2.8.3 - P_{SP} Factors Dependent on Cable Type and Failure Mode			
State of Cable Knowledge	**Thermoset**	**Thermoplastic**	**Armored**
No available information about cable type or current limiting devices (worst-case value from NEI 00-01 Table 4-4)		.6	
Cable type known, no other information known (NOI)	.6	.6	.15
Inter-cable interactions only	.02	.20	
In conduit, cable type known, NOI	.30	.6	
In conduit, inter-cable only	.01	.20	
In conduit, intra-cable	.075	.3	

- In evaluating ex-control room actions in response to plant conditions, use the same logic, as contained in the first two bullets (○) under "Incorporate the impact of the human error contribution" from the previous page, to generate CCDP values.
- For remote shutdown operations, the human error probability obtained from the appropriate table is compared to the result of evaluating the appropriate initiating event worksheet with credit only for those SSCs called for in the procedure. The more conservative value is used. A detailed analysis of individual human actions should not be attempted in the Phase 2 SDP.

Special Cases:

- Findings Against the Post-Fire SSD Program
  Findings against a licensee's post-fire SSD program would be manifested by an increase in the likelihood that operators fail to achieve SSD given a fire. Such findings may have implications for fires in several locations. The Phase 2 SDP should only be applied when the finding can be identified with a specific fire area. For findings with plant-wide consequences, a Phase 3 SDP assessment should be performed.

- Findings Related to Circuit Issues
  In a similar manner to the SSD findings discussed above, circuit issues may have implications for several fire areas, since the cable associated with the circuit may run through several locations. For anything other than the case where the effect is localized, a Phase 3 SDP analysis should be performed. When there is a known issue associated with an area in which an unrelated finding is being assessed, the CCDP evaluation should account for the impact, which could be either the creation of an initiating event, or the failure of a system to perform its function.

Step 2.9 - Quantification and Preliminary Significance Determination

In Step 2.9, a final quantification of the FDS scenarios of interest is calculated, and a preliminary determination of a findings significance is assigned.

The estimated risk contribution or screening CDF, for each fire scenario is based on the product of the following factors:

$$\Delta CDF_{2.8} \approx DF \times \sum_{i=1}^{n} \left[F_i \times SF_i \times \Pi AF_{i\,2.4} \times PNS_i \times CCDP_i \right]_{\text{All Scenarios}}$$

Where:

n	=	number of fire scenarios evaluated for a given finding (covering all relevant FDSs)
DF	=	Duration factor from Step 1.4
F_i	=	Fire frequency for the fire ignition source i from Task 2.4.1
SF_i	=	Severity factor for scenario i from Task 2.4.1
$AF_{i\,2.4}$	=	Ignition source specific frequency adjustment factors from Step 2.4
PNS_i	=	Probability of non-suppression for scenario i from Step 2.7
$CCDP_i$	=	Conditional core damage probability for scenario i from Step 2.8

- If the value of $\Delta CDF_{2.8}$ is lower than or equal to 1E-6, then the finding screens to Green, and the analysis is complete.
- If the value of $\Delta CDF_{2.8}$ is greater than 1E-6, then the finding is potential risk significant.

Table 2.9.1- Risk Significance Based on ΔCDF	
Frequency Range/ry	**SDP Based on ΔCDF**
$\geq 10^{-4}$	Red
$< 10^{-4} - 10^{-5}$	Yellow
$< 10^{-5} - 10^{-6}$	White
$< 10^{-6}$	Green

Intentionally Blank